

# Switchyard Rookie Book

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[Complete Device Schematic of P1-P2-P3-SY-Meson](#)

### ***Acknowledgements***

Maggie Stauffer, Chip Edstrom and Chuck Brown, have generated, or collected from previous versions, the material in this edition of the Switchyard Rookie Book.

Corrections and additions are always welcome. We especially hope to keep the [Tuning Guide](#) current. Hopefully it can be kept in sync with any changes in the settings of the SY120 beam line or the MTest and MCenter beamlines as they are modified to follow the requirements of various experimental users. Please help us by bringing any incorrect or obsolete material to our attention.

### ***Note about this version:***

During the last Tevatron Fixed Target run in 1999, 800 GeV beam was split in Switchyard to one of three possible paths: west down the Meson line, straight on to Neutrino & Muon lines, or east down the Proton line. The Meson, Neutrino/Muon and Proton areas themselves were further split into several more beamlines, serving a multitude of users.

Currently, the Tevatron is used for HEP collider physics and no longer delivers 800 GeV beam to Switchyard. Instead, 120 GeV beam is delivered by the Main Injector, extracted into the P1, P2 & P3 lines, and is then deflected to the original Switchyard beam line, where it traverses Enclosures B and C and the F-manholes, finally arriving in the Meson Area, the only remaining operational Fixed Target area. In M01, beam is further split into two beam lines that serve our two existing beam lines at this time, Meson Center and Meson Test.

Nowadays, a very small fraction of the Switchyard and the Fixed Target Areas are used, compared to days of yore. However, in the course of your travels you may encounter obsolete devices, power supplies, tunnel enclosures and service buildings. To that end, some notes in this Rookie Book provide historical information that you might find handy to know. Rest assured that we have made every effort to include only *relevant* obsolete information!

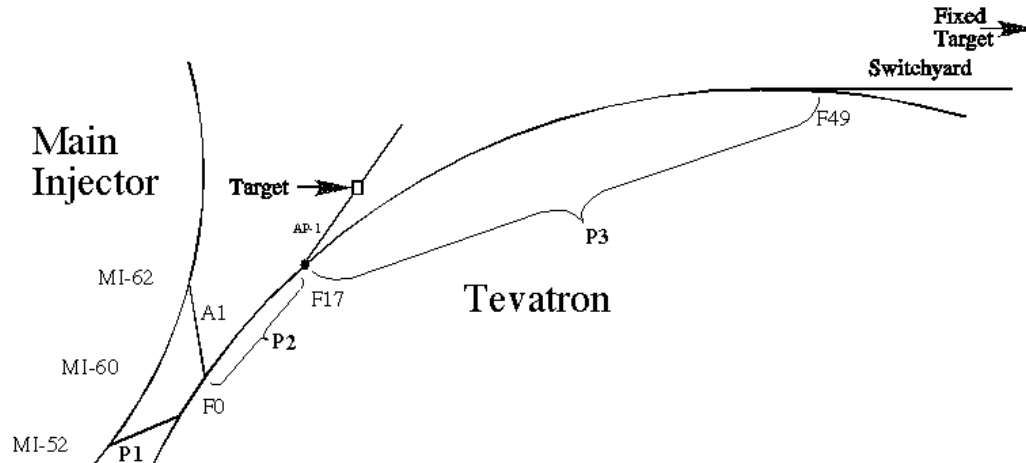
Happy trails.

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Notes:

## Chapter 1: General Information

### ***GEOGRAPHY***



### **Main Injector**

Beam destined for Switchyard is accelerated to 120Gev in the Main Injector on a \$20 or \$21 event. It can be extracted in two ways: slow spill and single-turn extraction. Slow spill, currently the most common operational method, uses the QXR quadrupole circuit to resonantly extract beam over 1 second (\$20 event) or 4 seconds (\$21 event). In single-turn extraction, beam is extracted with the MI-52 kicker/Lambertson combination.

### **P1 line**

The P1 line starts in the Main Injector at the 52 location and bends beam up toward the Tevatron, ending at T:ILAM at Tevatron location F0. Besides beam to Meson, this line is used for proton injection into the Tevatron and beam to and from Pbar.

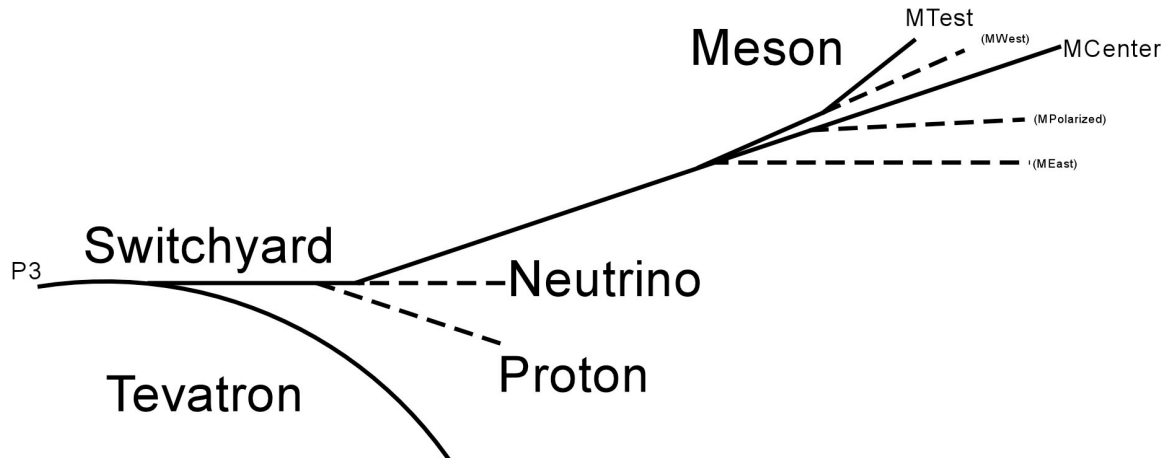
### **P2 line**

For extraction to Switchyard and Pbar, beam coasts straight through the field-free region of T:ILAM into the P2 line, which extends from F11 to F17. If the I:F17B3 dipole ramps to high current, beam will be deflected into the AP1 line; otherwise, on a \$20 or \$21 event, I:F17B3 ramps down to zero current and the beam continues through to the P3 line.

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## P3 line

The P3 line, sometimes referred to as the ‘Main Ring Remnant’, follows the curvature of the Tevatron from F17 to F49. All magnets in the P3 line are powered by S:HP3US, S:HP3DS & S:QP3; HP3DS, which powers the second half of the P3 dipoles, is the critical device for the Transfer Hall and Switchyard enclosures B & C.



## Switchyard

Switchyard officially begins in the Transfer Hall at F49, where the P3 line ends and the beamline branches away from the Tevatron to continue onwards through the Transfer Hall to the “Continental Switchyard,” i.e. Enclosures B and C, D & E.

Early in Enclosure C is the beam’s first opportunity to branch in one of two directions. The value of vertical trim S:VT103X, located in downstream Enclosure B, determines whether the beam will pass through the field-free region of S:MLAM to the SY dump (located in Encl C), or through the magnetic field gap to be bent west and continue through Enclosure-C onward to Meson. S:MLAM1 & 2, and S:V204 are the critical devices for the F-manholes and the Meson Lab tunnel Enclosures, M01 to M05.

Next up is the F1 manhole, notable for containing the FSEP7 and FSEP8 electrostatic septa that are capable of splitting the beam vertically into 2 streams.

Finally, the two streams of beam (FSEP7 and FSEP8 are kept at the same height and hence act as a single septa!) continue through the F2 and F3 manholes to the first Meson Area enclosure, M01.

*Note about Enclosures C, D & E*

This multiply-named single Switchyard enclosure is a combination of three beamline tunnels. The western tunnel, C, contains the beamline servicing Meson. The Neutrino beamline formerly traveled straight ahead through the G1 stub and the G2 manhole. The Proton beamline traveled through enclosures D & E on to J. Enclosure J was once part of this same enclosure; however, the interlocked gate has been moved from the downstream end of enclosure-J to the downstream end of enclosure-E. Though Encl J is now a separate enclosure, the key fobs still reflect the historical name “C, D, E & J.”

**Meson**

At the upstream end of M01, the 2 vertically separated streams of beam coming uphill from the F-enclosures have now diverged to about 1 inch apart. The beams rising up to M01 from Enclosure-C are rising up at an angle of about 1 degree. They are first bent horizontally by M01D. The lower stream of protons travels through the center, field-free region of the MW1W/ME1E 3-way Lambertson magnet. F:MC1D, a critical device for MC6, MC7 & MC8, then bends the beam slightly downward into the MCenter beamline. The upper stream is bent horizontally west into the MTest/MWest beamline by F:MW1W, the critical device for MTest enclosures MT6A and MT6B. If the critical devices are off, the Meson Target Train collimators absorb the beam.

MTest and MCenter share enclosures M01, M02, M03 and M05. By the end of M05, the beamlines have diverged sufficiently so there is finally room for independent enclosures, target halls, and shielding for each beam line. MTest concludes in enclosures MT6A & MT6B, while beam to MCenter continues through enclosures MC6 to MC7. MC8 and the empty MBottom enclosure MB7 do not contain any MCenter beam line elements, but due to potential muon radiation from the MC6 target station, they must be interlocked for MCenter beam operation.

**Historical note: Border dispute**

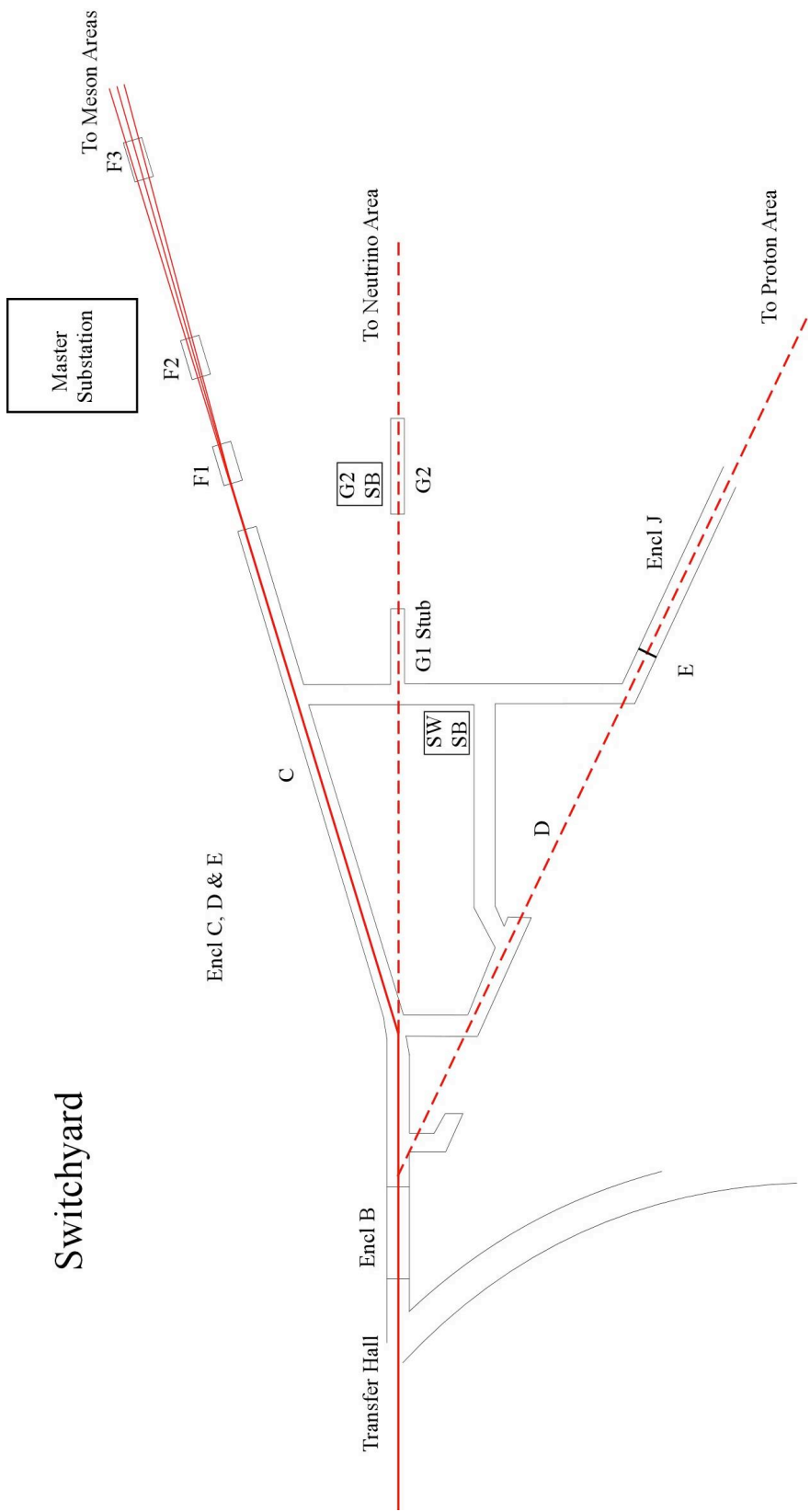
Technically, the Meson area begins at M01; however, there are 3 Meson trim magnets, F:M00U, F:M00H and F:M00V, and a quad doublet, F:Q230, located in the Switchyard F2 and F3 manholes. These devices are powered by supplies located in MS1;

## **Switchyard Rookie Book**

the F1-manhole devices are powered by supplies in the G2 service building. So, rather than thinking of Meson beginning at M01, one can consider Meson to “begin” with the devices powered at MS1, even though they are located in the F2 and F3 manholes.

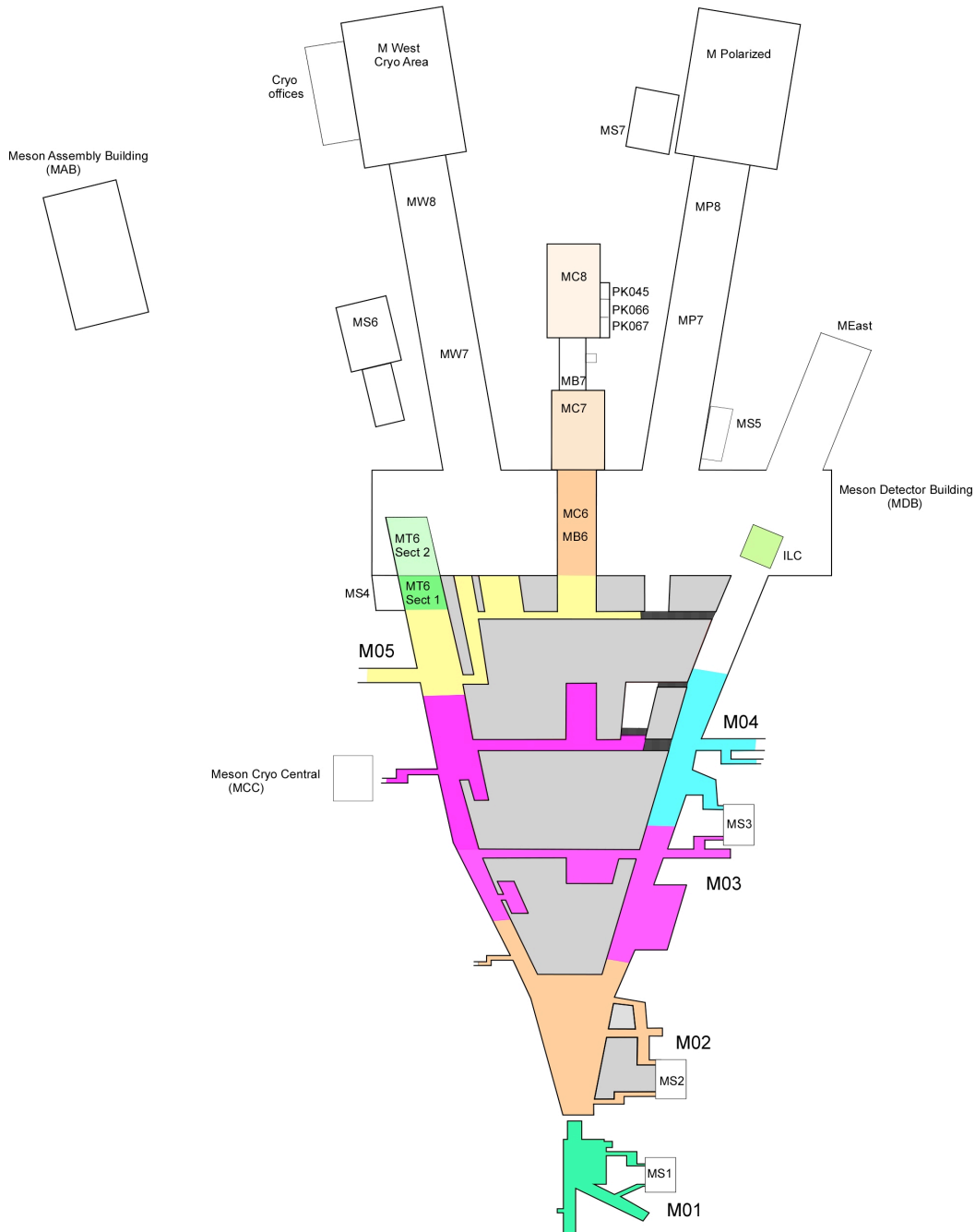


Switchyard Enclosure Map



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## Fermilab Meson Enclosures

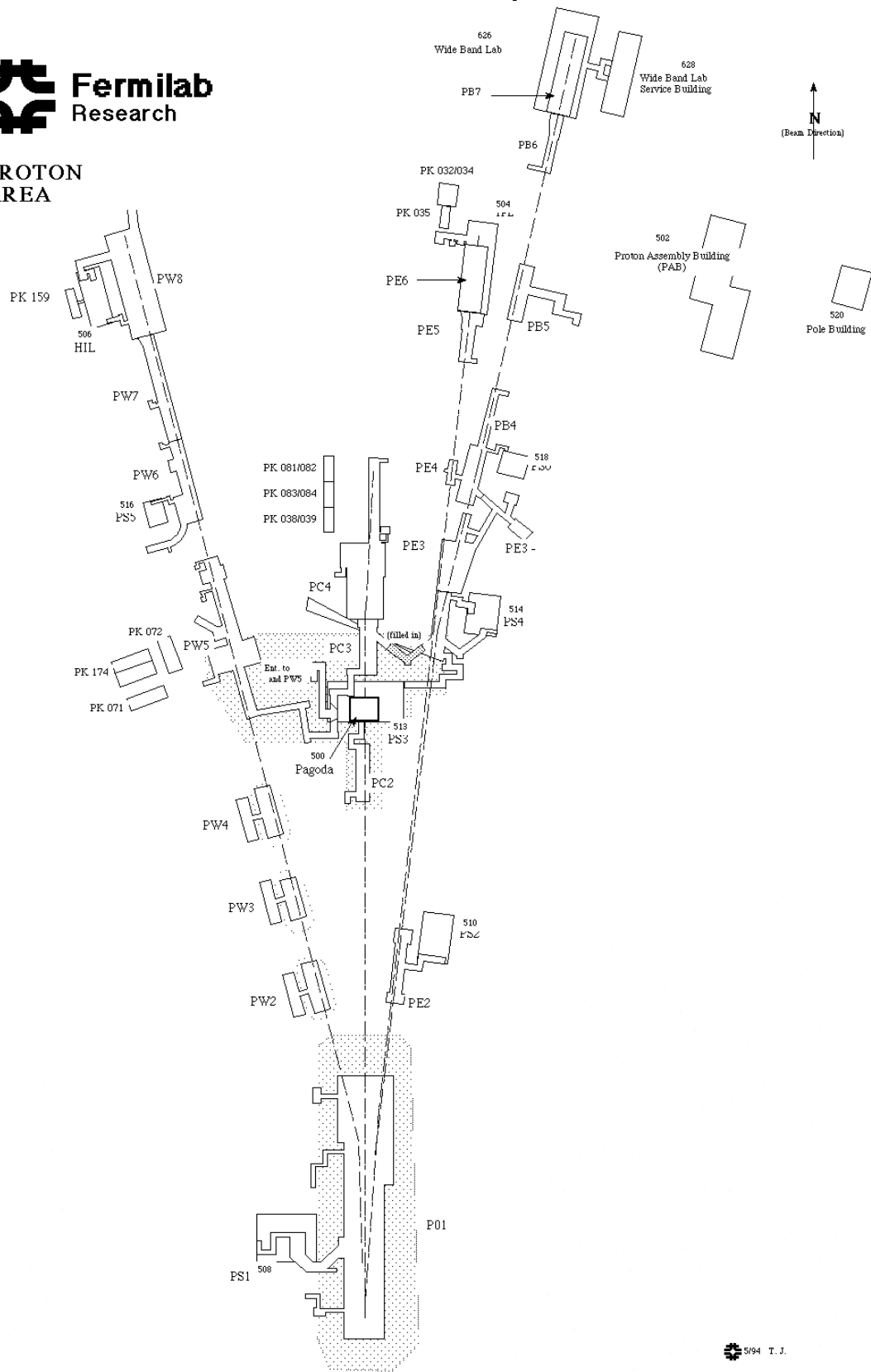


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Proton Area Map



PROTON  
AREA



5/94 T. J.

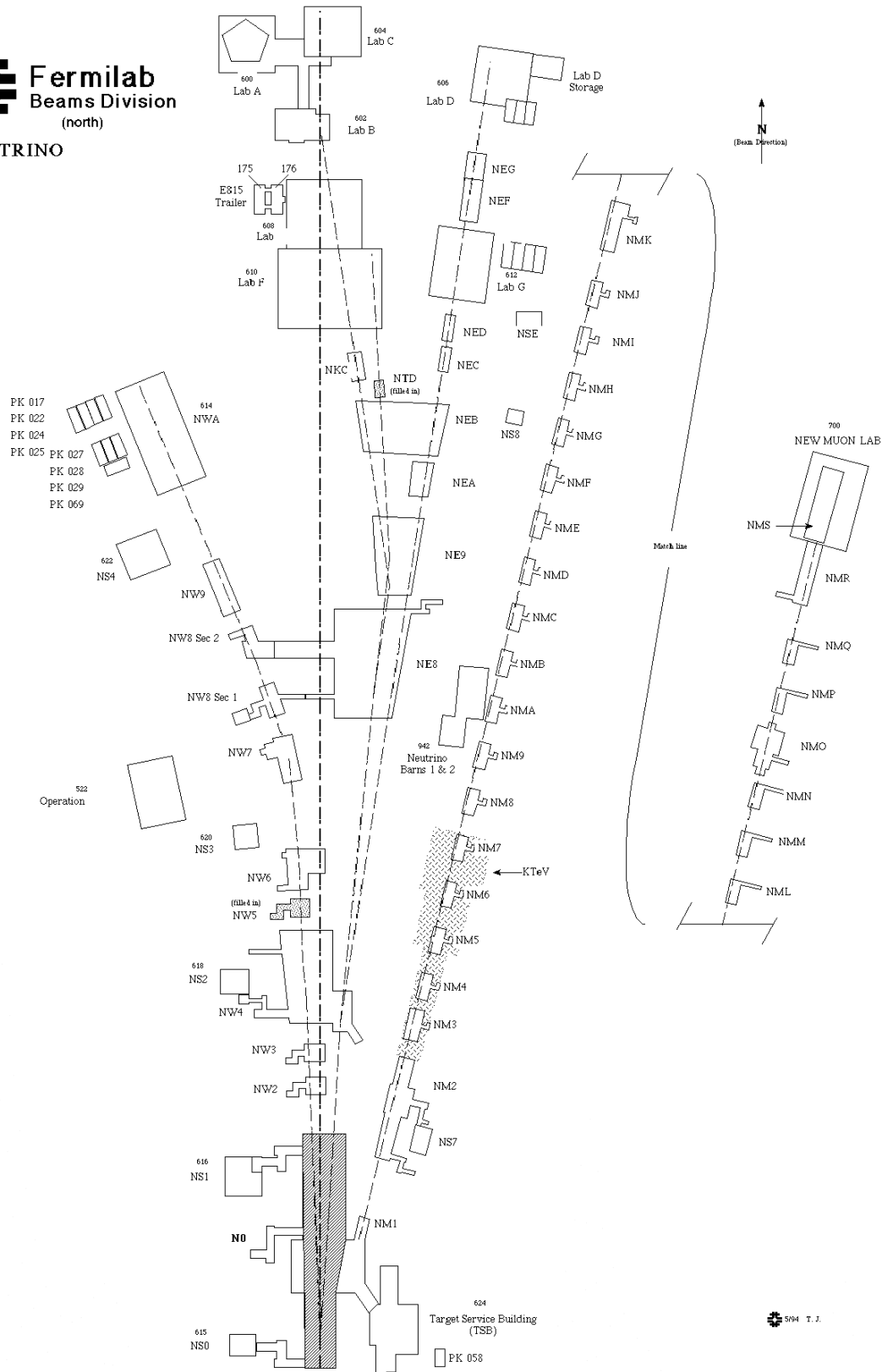
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## Neutrino Area Map



**Fermilab**  
Beams Division  
(north)

NEUTRINO



## NAMING CONVENTION

### Switchyard

Switchyard devices are prefixed by “S:” and are of the form:

**S:DN** or **S:ND** (vacuum devices only)

#### D. Device Type

|    |                            |
|----|----------------------------|
| BL | - Blower                   |
| BV | - Beam valve               |
| CC | - Cold cathode             |
| H  | - Horizontal dipole magnet |
| HP | - Horizontal BPM           |
| HT | - Horizontal trim magnet   |
| IV | - Isolation valve          |
| L  | - Loss monitor             |
| Q  | - Quadrupole magnet        |
| RV | - Roughing valve           |
| RP | - Roughing pump            |
| S  | - SWIC                     |
| TC | - Thermocouple             |
| V  | - Vertical dipole magnet   |
| VP | - Vertical BPM             |
| VT | - Vertical trim magnet     |

#### N. Number of the tunnel location/associated beamline based on the numbering scheme:

| Magnet Number | Lines Affected                | Location      |
|---------------|-------------------------------|---------------|
| Less than 100 | Meson, Neutrino, Muon, Proton | Transfer Hall |
| 100-109       | Meson, Neutrino, Muon         | Enc. B        |
| 100-109       | SY Dump, Neutrino, Muon       | Enc. C        |
| 110-119       | Neutrino, Muon                | Enc. G1       |
| 120-129       | Neutrino                      | Enc. G2       |
| 420-429       | Muon                          | Enc. G2       |
| 200-209       | Meson                         | Enc. C        |
| 210-219       | Meson                         | Enc. F1       |
| 220-229       | Meson                         | F2 Manhole    |
| 230-239       | Meson                         | F3 Manhole    |
| 300-306       | Proton                        | Enc. B, C, D  |
| 307-319       | Proton                        | Enc. E        |

Loss monitors contain a descriptive name, such as the name of the magnet they’re nearest. For example, LH90 is the loss monitor found on top of the H90 magnet.

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A magnet and its associated power supply generally have the same name. In the case where more than one magnet is powered by the same supply an appropriate name is chosen.

The D/A (setting) of a magnet's power supply will always be positive; however, the A/D (readback) can be either polarity, which sometimes(!) indicates useful information about the direction of the magnet's influence on the beam. The convention is (but don't trust polarities ever!):

| A/D Polarity    | +     | -       |
|-----------------|-------|---------|
| Quad            | Focus | Defocus |
| Vertical Dipole | Up    | Down    |
| Horiz. Dipole   | West  | East    |

## Fixed Target

Enclosure names are of the form

ABC

### A. Area

M - Meson  
N - Neutrino  
P - Proton

### B. Beamline

0 - Special case where the device or enclosure contains multiple beamlines  
T - Test  
W - West  
C - Center  
B - Bottom  
E - East  
P - Polarized  
M - Muon  
K - KTeV

### C. Enclosure number – 1-9, continuing with A-Z if there are more than 9

Example: the enclosure name MC6 means:

M = Meson area  
C = Center  
6 = The 6th enclosure containing Meson Center beamline

The Meson Area beamline devices are prefixed with an “F:” (for Fixed Target) and are of the form:

F:ABCD

#### D. Device Function

|      |                                     |
|------|-------------------------------------|
| AN   | - Analyzing magnet                  |
| AV   | - Actuated valve                    |
| BD   | - Beam dump                         |
| BL   | - Blower                            |
| BS   | - Beam stop                         |
| BV   | - Beam valve                        |
| CC   | - Cerenkov counter                  |
| CF   | - Fixed-hole collimator             |
| CH   | - Horizontal collimator             |
| CV   | - Vertical collimator               |
| D    | - Downward-bending dipole magnet    |
| E    | - East-bending dipole magnet        |
| FP   | - Scintillating Fiber Plane Chamber |
| H    | - Horizontal trim magnet            |
| IC   | - Ion chamber                       |
| L    | - Loss monitor                      |
| MV   | - Manual valve                      |
| P    | - Pinhole Collimator                |
| PG   | - Pirani gauge                      |
| PWC  | - Proportional wire chamber         |
| Q    | - Quadrupole magnet                 |
| RP   | - Roughing pump                     |
| RV   | - Roughing valve                    |
| SC   | - Scintillation counter             |
| SEM  | - Secondary emission counter        |
| T    | - Toroid magnet                     |
| TCOL | - Pinhole collimator                |
| TGT  | - Target                            |
| TLM  | - Total loss monitor                |
| TP   | - Turbo pump                        |
| TS   | - Spoiler magnet                    |
| U    | - Upward-bending dipole magnet      |
| V    | - Vertical trim magnet              |
| W    | - West-bending dipole magnet        |
| WC   | - Wire chamber (SWIC)               |

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Example: The device name F:M01D-2 means:

|    |   |  |
|----|---|--|
| F: | = | Fixed target device                                  |
| M  | = | Meson area   |
| 0  | = | Contains multiple beamlines                          |
| 1  | = | Enclosure number 1                                   |
| D  | = | Downward-bending dipole                              |
| -2 | = | The second magnet in a string of magnets called M01D |

## Note about M03/M04

In the past, M03 & M04 were divided in the same straightforward manner as other enclosures (M04 was downstream of M03 and both contained MT & MC devices). In 2005, the gates were rearranged, and now M03 contains the entire length of MTest & MCenter beamlines between M02 & M05; M04 has no operational devices in it. **Hence an exception to the naming convention: devices named MT3, MC3, MT4 and MC4 are now all in the M03 enclosure.** However, since M03 & M04 share a key and an ESS this doesn't affect what gets turned off for an access; they are separate enclosures only for the search and secure.



## Service Buildings

Service building names are typically of the form **ASC**, where “S” stands for Service.

There are various assembly buildings, equipment and control rooms, laboratories, and other buildings in the Fixed Target area that have names with very little or no association to their beamline location. They were named a long time ago and now we’re stuck with them.

Here is a list of external beamline building names, what the names mean (if there are explanations), and where the buildings are located.

### External Beamline Buildings

|                  |  |
|------------------|--|
| HIL              | High Intensity Lab; associated with PW8            |
| Lab A            | Associated with NWB                                |
| Lab B            | Associated with NCG                                |
| Lab C            | Associated with NCH                                |
| Lab D            | Associated with NEH                                |
| Lab E            | Associated with NCF                                |
| Lab F            | Associated with NCE                                |
| Lab G            | Associated with NEE                                |
| Large White Barn | White barn located near enclosures NW8 and NMC     |
| MAB              | Meson Assembly Building                            |
| MCC              | Meson Central Cryogenics                           |
| MDB              | Meson Detector Building                            |
| MSB              | Magnet Storage Building; located near PAB          |
| New Muon         | Associated with NMS                                |
| Old Muon         | Associated with NWA                                |
| PAB              | Proton Assembly Building, located east of PE5      |
| Pagoda           | Associated with PS3                                |
| Pole Building    | Small building located just east of PAB            |
| Small White Barn | White barn located near enclosures NW8 and NMC     |
| TPL              | Tag Photon Lab; associated with PE6                |
| TSB              | Target Service Building (Linked to N01 via tunnel) |
| WBL              | Wide Band Lab; associated with PB7                 |

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Notes:

## Chapter 2: Power Supplies

Every device in the tunnel is hooked up to one or more power supplies. The switchyard and Meson beam lines, however, are different from the circular accelerators in that most devices have their own power supplies. There are not many common bus systems that supply current to a long string of magnets. Most magnets have their own individual power supply and individual ramp generator.

One exception to this rule is the P3 line (also known as the Main Ring Remnant), which is powered primarily by 3 main power supplies: S:HP3US, S:HP3DS, and S:QP3. QP3 powers all the quads in the P3 line. HP3US powers the upstream Main Ring-style dipoles between F17 and F34, and HP3DS powers the remaining (downstream) dipoles from F35 to F48. These two dipole power supplies are Switchyard critical devices; Steve Hays is the expert for these supplies.

MOS 89 powers all 3 of these P3 power supplies, so they do not require extra LOTO for F-sector access. However, some of the downstream quads and dipoles extend into Transfer Hall (which begins at F47), which is why HP3DS and QP3 (but not HP3US) must be switched off and LOTOed for Transfer Hall access.

Power supplies in the P1 and P2 lines are also ramped on Switchyard events. For details on these supplies, refer to the [Beam Transport Lines](#) chapter of the [Main Injector Rookie Book](#).

At present there are seven different types of power supplies used in Switchyard & Meson:

- \* TRANSREX-500kW
- \* TRANSREX-240kW
- \* LING
- \* ACME
- \* P=EI 20kW
- \* Glassman
- \* 4-quadrant corrector supplies

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## ***TRANSREX 500kW***

These are high-voltage, high-current power supplies. They are used on the large, conventional-type magnet strings. They have a maximum output of 500kW, hence the name. The Transrex-500kW is the only type of supply to be put in series with another supply (for S:MLAM, F:M01D, and each of the MCenter analyzing magnets F:MC7AN1 & F:MC7AN2). In these cases, only one supply is connected to ground. The Transrex-500kW supplies have a maximum output of 5000 Amps at 100volts, or a maximum voltage of 400 VDC at 1250 Amps depending on the settings of the internal voltage and current taps. Both these conditions cannot be obtained simultaneously ( $400\text{ V} * 5000\text{ A} = 2\text{ MW}$ ).



## ***TRANSREX-240kW***

The Transrex-240kW power supply maximum outputs are 1200 Amps at 200 VDC or 800 VDC at 300 Amps. Again these cannot be reached simultaneously. This type of supply is currently only used for 3 devices: F:M00U, F:MW1W and F:MC1D.



## ***LING***

The Ling power supply was specifically used for Switchyard quadrupoles. Of these, only Q100, Q101 and Q202 remain on Lings (the rest are powered by 4-quadrant corrector power supply trim regulators). The Ling is a 55 kW power supply with maximum 200 Amps and 550 VDC, again not simultaneously.



### **ACME**

Acme supplies are used exclusively in Meson; they power a few dipole magnets and all quads except the high-current F:MC6Q2 & 5. They are rated at 50kW (500V/100A) or 22.5kW (225V/100A).



### **P=EI 20kW**

These small 20kW P=EI (Power Energy Industries) power supplies have a maximum current of 200 Amps and maximum voltage of 100 VDC (not simultaneously).



### **GLASSMAN**

There is only one Glassman supply in Switchyard, which powers the FSEPS septa magnets.



### **4-Quadrant Corrector Supplies**

The following corrector bulk supplies contain trim dipoles and quads used in Switchyard: I:CPS60N, I:CPS60S, I:CPSF1, S:CPSF1, S:CPSTG, S:CPSSY & S:CPSG2. Each bulk supply supplies power to a number of regulators; each regulator powers one trim dipole or one quad. It is necessary to reset the bulk supply in order to clear trip status on any individual corrector. There are many versions of this ‘Bartleson’ supply used around the complex; Switchyard’s are rated at 50A/120V.

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## Trim Chassis Inventory\*

|                       | P1      | P2      | P3      | T-Hall  | Encl B   | Encl C   | F Manh   |
|-----------------------|---------|---------|---------|---------|----------|----------|----------|
|                       | I:HT701 |         |         |         |          |          |          |
|                       | I:HT702 |         |         |         |          |          |          |
|                       | I:VT703 |         |         |         |          |          |          |
| <b>I:CPS6S</b>        | I:HT704 |         |         |         |          |          |          |
| (MI trims not listed) | I:VT705 |         |         |         |          |          |          |
|                       | I:HT706 |         |         |         |          |          |          |
|                       | I:VT707 |         |         |         |          |          |          |
|                       | I:HT708 |         |         |         |          |          |          |
|                       | I:VT709 |         |         |         |          |          |          |
|                       | I:HT710 |         |         |         |          |          |          |
| <b>I:CPS6N</b>        | I:VT711 |         |         |         |          |          |          |
| (MI trims not listed) | I:HT712 |         |         |         |          |          |          |
|                       | I:VT713 |         |         |         |          |          |          |
|                       | I:HT714 |         |         |         |          |          |          |
|                       |         | I:VTF12 | S:HTF26 |         |          |          |          |
|                       |         | I:HTF13 | S:VTF27 |         |          |          |          |
|                       |         | I:VTF14 | S:HTF28 |         |          |          |          |
| <b>I:CPSF1</b>        |         | I:HTF15 | S:HTF36 |         |          |          |          |
|                       |         | I:VTF16 | S:VTF37 |         |          |          |          |
|                       |         | I:HTF17 |         |         |          |          |          |
|                       |         | I:VTF17 |         |         |          |          |          |
| <b>S:CPSF1</b>        |         |         | S:VTF18 |         |          |          |          |
|                       |         |         | S:VTF19 |         |          |          |          |
|                       |         |         |         | S:Q80X  | S:HT100X | S:VT201X |          |
|                       |         |         |         | S:HT90X | S:VT101X | S:Q201X  |          |
| <b>S:CPSTG</b>        |         |         |         | S:VT91X | S:VT102X | S:Q203X  |          |
|                       |         |         |         | S:VT92X | S:VT103X | S:Q204X  |          |
|                       |         |         |         | S:Q90X  | S:Q102X  | S:Q205X  |          |
|                       |         |         |         |         |          | S:HT105X |          |
|                       |         |         |         |         |          | S:VT105X |          |
|                       |         |         |         |         |          | S:HT201X |          |
| <b>S:CPSSY</b>        |         |         |         |         |          | S:HT202X |          |
|                       |         |         |         |         |          | S:VT202X |          |
|                       |         |         |         |         |          | S:Q206X  |          |
|                       |         |         |         |         |          | S:Q207X  |          |
|                       |         |         |         |         |          | S:Q208X  |          |
|                       |         |         |         |         |          |          | S:HT210  |
| <b>S:CPSG2</b>        |         |         |         |         |          |          | S:QT210X |
|                       |         |         |         |         |          |          | S:QT211X |
| <b>BADMAB</b>         |         |         |         |         |          |          | S:VT210X |

\*453 cards control the bulk supplies that power the quads and trim dipoles (see ACNET page S12).

***P1/P2/P3/Switchyard/Meson Power Supplies & Loads***

| Device  | PS Type      | Location | Encl       | Load                 | Card | Mode   |
|---------|--------------|----------|------------|----------------------|------|--------|
| I:LAM52 |              | MI-52    | MI         | Crdev Lambertson (3) | 468  | Ramped |
| I:V701  |              | MI-52    | MI         | Crdev C-mags (4)     | 468  | Ramped |
| I:Q701  |              | F0       | MI         | MR quad              | 468  | Ramped |
| I:HT701 | I:CPS6S      | MI-60S   | MI         | TRIM                 | 453  | Ramped |
| I:VT701 | I:CPS6S      | MI-60S   | MI         | TRIM                 | 453  | Ramped |
| I:Q702  |              | F0       | MI         | MR quad              | 468  | Ramped |
| I:HT702 | I:CPS6S      | MI-60S   | MI         | TRIM                 | 453  | Ramped |
| I:Q703  |              | F0       | MI         | MR quads (7)         | 468  | Ramped |
| I:HV703 |              | F0       | MI         | MR dipoles (15)      | 468  | Ramped |
| I:VT703 | I:CPS6S      | MI-60S   | MI         | TRIM                 | 453  | Ramped |
| I:HT704 | I:CPS6S      | MI-60S   | MI         | TRIM                 | 453  | Ramped |
| I:VT705 | I:CPS6S      | MI-60S   | MI         | TRIM                 | 453  | Ramped |
| I:HT706 | I:CPS6S      | MI-60S   | MI         | TRIM                 | 453  | Ramped |
| I:VT707 | I:CPS6S      | MI-60S   | F-sector   | TRIM                 | 453  | Ramped |
| I:HT708 | I:CPS6S      | MI-60S   | F-sector   | TRIM                 | 453  | Ramped |
| I:VT709 | I:CPS6S      | MI-60S   | F-sector   | TRIM                 | 453  | Ramped |
| I:Q710  |              | F0       | F-sector   | MR quad              | 468  | Ramped |
| I:HT710 | I:CPS6N      | MI-60N   | F-sector   | TRIM                 | 453  | Ramped |
| I:Q711  |              | F0       | F-sector   | MR quad              | 468  | Ramped |
| I:VT711 | I:CPS6N      | MI-60N   | F-sector   | TRIM                 | 453  | Ramped |
| I:QF12  |              | F0       | F-sector   | MR quad              | 468  | Ramped |
| I:HT712 | I:CPS6N      | MI-60N   | F-sector   | TRIM                 | 453  | Ramped |
| I:QF13  |              | F0       | F-sector   | MR quad              | 468  | Ramped |
| I:VT713 | I:CPS6N      | MI-60N   | F-sector   | TRIM                 | 453  | Ramped |
| I:QF14  |              | F0       | F-sector   | MR quad              | 468  | Ramped |
| I:V714  |              | F0       | F-sector   | MR dipoles           | 468  | Ramped |
| I:HT714 | I:CPS6N      | MI-60N   | F-sector   | TRIM                 | 453  | Ramped |
| I:QF11A | 75kW Spang   | F0       | F-sector   | MR quad              | 468  | Ramped |
| I:QF11B | 75kW Spang   | F0       | F-sector   | MR quad              | 468  | Ramped |
| I:HV711 | 75kW Spang   | F0       | F-sector   | MR dipoles (2)       | 468  | Ramped |
| I:HTF11 | I:CPS6N      | MI-60N   | F-sector   | TRIM                 | 453  | Ramped |
| I:QF12  | 500kW P=EI   | F0       | F-sector   | MR quads (2)         | 468  | Ramped |
| I:HV712 | Main Ring PS | F1       | F-sector   | MR dipoles (20)      | 468  | Ramped |
| I:VTF12 | I:CPSF1      | F1       | F-sector   | TRIM                 | 453  | Ramped |
| I:HTF13 | I:CPSF1      | F1       | F-sector   | TRIM                 | 453  | Ramped |
| I:VTF14 | I:CPSF1      | F1       | F-sector   | TRIM                 | 453  | Ramped |
| I:HTF15 | I:CPSF1      | F1       | F-sector   | TRIM                 | 453  | Ramped |
| I:VTF16 | I:CPSF1      | F1       | F-sector   | TRIM                 | 453  | Ramped |
| I:HTF17 | I:CPSF1      | F1       | F-sector   | TRIM                 | 453  | Ramped |
| I:VTF17 | I:CPSF1      | F1       | F-sector   | TRIM                 | 453  | Ramped |
| I:F17B3 | Main Ring PS | F2       | F-sector   | Crdev MR dipole      | 468  | Ramped |
| S:VTF18 | S:CPSF1      | F1       | F-sector   | TRIM                 | 453  | Ramped |
| S:VTF19 | S:CPSF1      | F1       | F-sector   | TRIM                 | 453  | Ramped |
| S:HP3US | Main Ring PS | F3       | F-sector   | MR dipoles (57)      | 468  | Ramped |
| S:HP3DS | Main Ring PS | F4       | TH, F-sect | MR dipoles (46)      | 468  | Ramped |

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|          |                    |     |            |                        |        |        |
|----------|--------------------|-----|------------|------------------------|--------|--------|
| S:QP3    | Main Ring PS       | F4  | TH, F-sect | MR quads (28)          | 468    | Ramped |
| S:HTF26  | I:CPSF1            | F1  | F-sector   | TRIM                   | 453    | Ramped |
| S:VTF27  | I:CPSF1            | F1  | F-sector   | TRIM                   | 453    | Ramped |
| S:HTF28  | I:CPSF1            | F1  | F-sector   | TRIM                   | 453    | Ramped |
| S:HTF36  | I:CPSF1            | F1  | F-sector   | TRIM                   | 453    | Ramped |
| S:VTF37  | I:CPSF1            | F1  | F-sector   | TRIM                   | 453    | Ramped |
| S:Q80X   | S:CPSTG            | TG9 | TH         | TRIM                   | 453    | Ramped |
| S:HT90X  | S:CPSTG            | TG9 | TH         | TRIM                   | 453    | Ramped |
| S:VT91X  | S:CPSTG            | TG9 | TH         | TRIM                   | 453    | Ramped |
| S:VT92X  | S:CPSTG            | TG9 | TH         | TRIM                   | 453    | Ramped |
| S:Q90X   | S:CPSTG            | TG9 | TH         | QUAD                   | 453    | Ramped |
| S:VH94   | Transrex 500-5     | TG8 | TH         | 2 EPB                  | 165    | Ramped |
| S:HT100X | S:CPSTG            | TG9 | B          | TRIM                   | 453    | Ramped |
| S:Q100   | Ling               | TG8 | B          | QUAD                   | 165    | Ramped |
| S:VT101X | S:CPSTG            | TG9 | B          | TRIM                   | 453    | Ramped |
| S:Q101   | Ling               | TG8 | B          | QUAD                   | 165    | Ramped |
| S:VT102X | S:CPSTG            | TG9 | B          | TRIM                   | 453    | Ramped |
| S:Q102X  | S:CPSTG            | TG9 | B          | QUAD                   | 453    | Ramped |
| S:VT103X | S:CPSTG            | TG9 | B          | TRIM                   | 453    | Ramped |
| S:MLAM   | Transrex 500-5 (2) | TG8 | C          | 2 LAM                  | 165    | Ramped |
| S:Q201X  | S:CPSTG            | TG9 | C          | QUAD                   | 453    | Ramped |
| S:Q202   | Ling               | TG8 | C          | QUAD                   | 165    | Ramped |
| S:HT105X | S:CPSSY            | SSB | C          | TRIM                   | 453    | Ramped |
| S:VT105X | S:CPSSY            | SSB | C          | TRIM                   | 453    | Ramped |
| S:VT201X | S:CPSSY            | SSB | C          | TRIM                   | 453    | Ramped |
| S:HT201X | S:CPSSY            | SSB | C          | TRIM                   | 453    | Ramped |
| S:H201   | Transrex 500-5     | SSB | C          | 14 EPB                 | 165    | Ramped |
| S:Q203X  | S:CPSTG            | TG9 | C          | QUAD                   | 453    | Ramped |
| S:HT202X | S:CPSSY            | SSB | C          | TRIM                   | 453    | Ramped |
| S:Q204X  | S:CPSSY            | SSB | C          | QUAD                   | 453    | Ramped |
| S:VT202X | S:CPSSY            | SSB | C          | TRIM                   | 453    | Ramped |
| S:Q205X  | S:CPSTG            | TG9 | C          | QUAD                   | 453    | Ramped |
| S:Q206X  | S:CPSSY            | SSB | C          | QUAD                   | 453    | Ramped |
| S:H202   | Transrex 500-5     | SSB | C          | 14 EPB                 | 165    | Ramped |
| S:H203   | Transrex 500-5     | SSB | C          | EPB                    | 165    | Ramped |
| S:Q207X  | S:CPSSY            | SSB | C          | QUAD                   | 453    | Ramped |
| S:Q208X  | S:CPSSY            | SSB | C          | QUAD                   | 453    | Ramped |
| S:V204   | Transrex 500-5     | SSB | C          | 2 EPB                  | 165    | Ramped |
| S:VT210X | BADMAB             | G2  | F1         | TRIM                   | BADMAB | DC     |
| S:QT210X | S:CPSG2            | G2  | F1         | QUAD                   | 453    | Ramped |
| S:HT210  | S:CPSG2            | G2  | F1         | TRIM                   | 218    | DC     |
| S:QT211X | S:CPSG2            | G2  | F1         | QUAD                   | 453    | Ramped |
| S:FSEP   | Glassman           | G2  | F1         | SEPTA (2)              | 118    | DC     |
| F:M00H   | P=EI               | MS1 | F2         | 4-4-30                 | 151    | DC     |
| F:M00V   | P=EI               | MS1 | F2         | 2.5-5.125-40           | 151    | DC     |
| F:M00U   | Transrex 240-1.2   | MS1 | F3         | 3 cooling ring dipoles | 1151   | DC     |
| F:MW1W   | Transrex 240-1.2   | MS1 | M01        | 6 3-way Lambertsons    | 1151   | DC     |
| F:MC1D   | Transrex 240-1.2   | MS1 | M01        | (1) Modified B1        | 1151   | DC     |



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|          |                    |     |         |                     |      |    |
|----------|--------------------|-----|---------|---------------------|------|----|
| F:M01D   | Transrex 500-5 (2) | MS1 | M01     | (7) Modified B1's   | 1151 | DC |
| F:MT2Q1  | ACME               | MS2 | M02     | 3Q120               | 1151 | DC |
| F:MT2Q2  | ACME               | MS2 | M02     | 3Q120               | 1151 | DC |
| F:MT2WD1 | Transrex 500-5     | MS2 | M02     | (2) 5-1.5-120 (EPB) | 1151 | DC |
| F:MT2WD2 | Transrex 500-5     | MS2 | M02     | (3) 6-3-120         | 1151 | DC |
| F:MT2V   | P=EI               | MS2 | M02     | 4-4-30              | 151  | DC |
| F:MT2WU  | Transrex 500-5     | MS2 | M02     | (5) 5-1.5-120 (EPB) | 1151 | DC |
| F:MC2Q1  | ACME               | MS2 | M02     | 3Q120               | 1151 | DC |
| F:MC2Q2  | ACME               | MS2 | M02     | 3Q120               | 1151 | DC |
| F:MC2V   | P=EI               | MS2 | M02     | 5.5-2.87-60         | 151  | DC |
| F:MC2H   | P=EI               | MS2 | M02     | 5.5-2.87-60         | 151  | DC |
| F:MT3Q1  | ACME               | MS3 | M03/M04 | 3Q120               | 1151 | DC |
| F:MT3Q2  | ACME               | MS3 | M03/M04 | 3Q120               | 1151 | DC |
| F:MT3Q3  | ACME               | MS3 | M03/M04 | 3Q120               | 1151 | DC |
| F:MT3Q4  | ACME               | MS3 | M03/M04 | 3Q120               | 1151 | DC |
| F:MT3V   | P=EI               | MS3 | M03/M04 | 4-4-30              | 151  | DC |
| F:MT3W   | Transrex 500-5     | MS3 | M03/M04 | (2) 5-1.5-120 (EPB) | 1151 | DC |
| F:MT3SW  | Transrex 500-5     | MS3 | M03/M04 | 5-1.5-120 (EPB)     | 1151 | DC |
| F:MT3U   | Transrex 240-1.2   | MS3 | M03/M04 | (2) 3D120           | 1151 | DC |
| F:MT4W   | Transrex 500-5     | MS3 | M03/M04 | EPB                 | 1151 | DC |
| F:MT4WL  | Gen 10 330         | MS3 | M03/M04 | EPB                 | 1151 | DC |
| F:MT4Q1  | ACME               | MS3 | M03/M04 | 3Q120               | 1151 | DC |
| F:MT4Q1L | Gen 100-33         | MS3 | M03/M04 | 3Q120               | 1151 | DC |
| F:MT4Q2  | ACME               | MS3 | M03/M04 | 3Q120               | 1151 | DC |
| F:MT4Q2L | Gen 100-33         | MS3 | M03/M04 | 3Q120               | 1151 | DC |
| F:MT4Q3  | ACME               | MS3 | M03/M04 | 3Q120               | 1151 | DC |
| F:MT4Q3L | Gen 100-33         | MS3 | M03/M04 | 3Q120               | 1151 | DC |
| F:MT4VT  | P=EI               | MS3 | M03/M04 | EPB                 | 1151 | DC |
| F:MT4HT  | P=EI               | MS3 | M03/M04 | EPB                 | 1151 | DC |
| F:MT4Q4  | ACME               | MS3 | M03/M04 | 3Q120               | 1151 | DC |
| F:MT4Q4L | Gen 100-33         | MS3 | M03/M04 | 3Q120               | 1151 | DC |
| F:MT4Q5  | ACME               | MS3 | M03/M04 | 3Q120               | 1151 | DC |
| F:MT4Q5L | Gen 100-33         | MS3 | M03/M04 | 3Q120               | 1151 | DC |
| F:MT4Q6  | ACME               | MS4 | M03/M04 | 3Q120               | 1151 | DC |
| F:MT4Q6L | Gen 100-33         | MS4 | M03/M04 | 3Q120               | 1151 | DC |
| F:MT5E   | Transrex 500-5     | MS4 | M03/M04 | (5) 5-1.5-120 (EPB) | 1151 | DC |
| F:MT5EL  | ESS 30 330         | MS4 | M03/M04 | (5) 5-1.5-120 (EPB) | 1151 | DC |
| F:MT5VT1 | P=EI               | MS4 | M05     | 4-4-30              | 3159 | DC |
| F:MT5Q1  | ACME               | MS4 | M05     | 3Q120               | 151  | DC |
| F:MT5Q1L | Gen 100-33         | MS4 | M05     | 3Q120               | 1151 | DC |
| F:MT5Q2  | ACME               | MS4 | M05     | 3Q120               | 151  | DC |
| F:MT5Q2L | Gen 100-33         | MS4 | M05     | 3Q120               | 1151 | DC |
| F:MT5VT2 | P=EI               | MS4 | M05     | 4-4-30              | 1151 | DC |
| F:MT5HT2 | P=EI               | MS4 | M05     | 4-4-30              | 1151 | DC |
| F:MC5Q1  | ACME               | MS4 | M05     | 3Q120               | 151  | DC |
| F:MC5Q2  | ACME               | MS4 | M05     | 3Q120               | 151  | DC |
| F:MC5H1  | ACME               | MS4 | M05     | 4-4-30              | 151  | DC |

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|          |                    |     |          |                     |      |    |
|----------|--------------------|-----|----------|---------------------|------|----|
| F:MC5V1  | ACME               | MS4 | M05      | 4-4-30              | 151  | DC |
| F:MC5U   | Transrex 500-5     | MS4 | M05, MC6 | (3) 5-1.5-120 (EPB) | 1151 | DC |
| F:MC6H1  | P=EI               | MS4 | MC6      | 4-4-30              | 1151 | DC |
| F:MC6H2  | P=EI               | MS4 | MC6      | 4-4-30              | 3159 | DC |
| F:MC6V1  | P=EI               | MS4 | MC6      | 4-4-30              | 1151 | DC |
| F:MC6V2  | P=EI               | MS4 | MC6      | 4-4-30              | 1151 | DC |
| F:MC6Q1  | ACME               | MS4 | MC6      | (2) 3Q120           | 1151 | DC |
| F:MC6Q2  | Transrex 500-5     | MS4 | MC6      | 4Q120               | 1151 | DC |
| F:MC6Q3  | ACME               | MS4 | MC6      | 3Q120               | 1151 | DC |
| F:MC6Q4  | ACME               | MS4 | MC6      | 3Q120               | 1151 | DC |
| F:MC6Q5  | Transrex 500-5     | MS4 | MC6      | 4Q120               | 1151 | DC |
| F:MC6Q6  | ACME               | MS4 | MC6      | 3Q120               | 1151 | DC |
| F:MC6D   | Transrex 500-5     | MS4 | MC6      | (4) 5-1.5-120 (EPB) | 151  | DC |
| F:MC7AN1 | Transrex 500-5 (2) | MS5 | MC7      | Jolly Green         | 3159 | DC |
| F:MC7AN2 | Transrex 500-5 (2) | MS5 | MC7      | Rosie               | 3159 | DC |

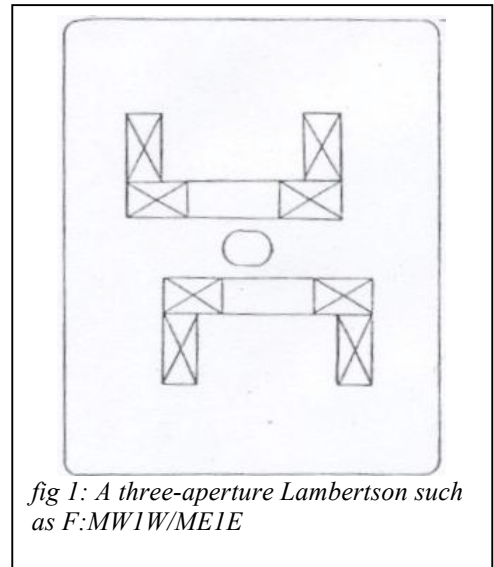
\* Note: most of the quad and dipole supplies in the M04 and M05 sections of the MTest beam line have had a second low-current power supply mounted on top of the existing high-current power supply. These additional power supplies are designated by an “L” appended to the name of the high current supply, thus F:MT4WL is the low-current supply mounted on top of the F:MT4W Transrex power supply in MS3. The interlocks on the piggy-back power supply combination prevent either power supply from being turned on if the other power supply is already on. Matt Kufer and Bryon Falconer are the experts on the new piggy-back supplies in the MTest beam line.

## Chapter 3: Magnets

Like any charged particle beam line, the Switchyard and External Beamlines require magnets to direct the beam and confine the beam to the beam pipe until it is delivered to its destination. This chapter assumes a basic understanding of magnets and related components. For a review of concepts and basic magnet configurations see the chapter on [Magnets](#) in the [Accelerator Concepts Rookie Book](#). As such this chapter will concern itself more with the kinds of magnets one can expect to find in the Switchyard. These include Lambertsons, Septa, EPB Dipoles, 3Q120 Quads, Main Ring B1 and B2 Dipoles, Main Ring Quads and Trims.

### **Lambertsons**

Lambertsons are special magnets with two or three apertures as shown in *fig 1*. One aperture is designed to be a field-free region, allowing beam to pass undeflected along its initial trajectory through the Lambertson. The other aperture or apertures have bend fields across them and will direct beam such that it leaves the Lambertson at an angle. If the dipole-field region of the Lambertson is not powered, however, no bend occurs and beam is not deflected by the Lambertson. For this reason Lambertsons can be used as critical devices. Switchyard is no exception, S:MLAM1 and S:MLAM2 are critical devices for the Meson Primary beam permit and F:MW1W (the upper coil of the MW1W/ME1E three-way Lambertson) is the critical device for MWest/MTest.



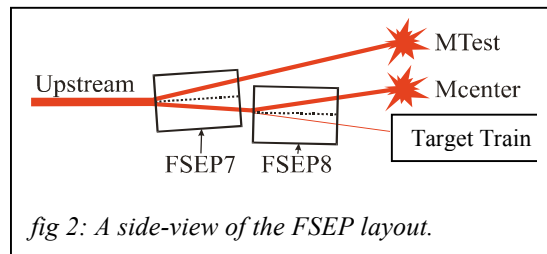
### **Septa**

An electrostatic septum splits beam along a plane defined by a row of grounded wires along the length of the septum. Parallel cathodes on either side of the wires are charged to a high potential resulting in a strong electric field across each gap. The beam on either side of the wires is deflected in opposite directions by the electric field. A

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septum is used to split the beam into two separate beams. Two septa can be used to split the beam into three separate beams – a three-way split.

The 2 FSEPS in the F1-enclosure split the proton beam into three beams, MWest/MTest, MCenter and MEast. The FSEPS are oriented to effect a vertical deflection with MWest on top. As seen in *fig 2*, FSEP7 is responsible for sending beam to MWest/MTest and FSEP8 divides the remainder between MCenter and MEast (the



MEast beam is always absorbed on the Meson Target Train in M01 since ME1E and the MEast beam line are permanently disabled). While one can adjust the upstream and downstream ends of a septa independently, in practice, a septa should remain relatively level; both the upstream and downstream stepper motors should be adjusted in unison to move the septa parallel to the beam.

**Note:** currently FSEP7 and FSEP8 are treated as a single septa. Thus FSEP8 should be placed at the same height as FSEP7; hence the proton beam is split into just two beams, MWest/MTest and MCenter.

For more information on tuning the relative MTest and MCenter intensities with the combined FSEP7/FSEP8 septa see the [Tuning Guide](#).

### EPBs

An EPB, or External Proton Beam, dipole is a conventional 10' long dipole used throughout switchyard. They have a 1.5" high gap by 4" gap width and are 120" long (a few 60" long EPBs exist also). They can be excited to a maximum field strength of about 15 kG at 1700 A. Due to their light weight, and hence poor field uniformity at high excitation, they are usually designed to run below about 1500 A. They provide the bulk of the bending power in the Switchyard and Meson Lab Beamlines.

**3Q120 Quads**

3Q120 quads have a 3” Internal Diameter (ID) and are 120” long. They have a maximum field gradient of about 5 kG/in at 100 A. These quads are poorly cooled and quite old, so for the sake of safety and longevity, they are usually run below 80 A.

**Main Ring B2 Dipoles and Quads**

The Main Ring B1 and B2 dipoles were the two standard types of dipoles formerly used in the Main Ring Accelerator. The aperture of a B1 is 1.5” gap by 5” wide and that of a B2 is 2” gap by 4” wide. These, along with the Main Ring-style quadrupoles, compose the bulk of the main bending and focusing magnets in the P1, P2, and P3 lines (P3 is also sometimes called the Main Ring remnant).

**Trims**

Trims are short, air-cooled dipoles used to make small corrections to the beam trajectory, particularly before splits and near experimental targets in the MTest and MCenter experimental areas. Many trims in the Switchyard run off 4-quadrant corrector supplies.

**Ramping Magnet Power Supplies**

Since the SY120 beam typically only pulses about once per minute, it makes sense to ramp the power supplies so that the magnets sit at zero current until the \$21 Switchyard beam cycle occurs. Most of the magnets in the SY120 beam line are ramped, see the table of magnets in the magnet chapter.

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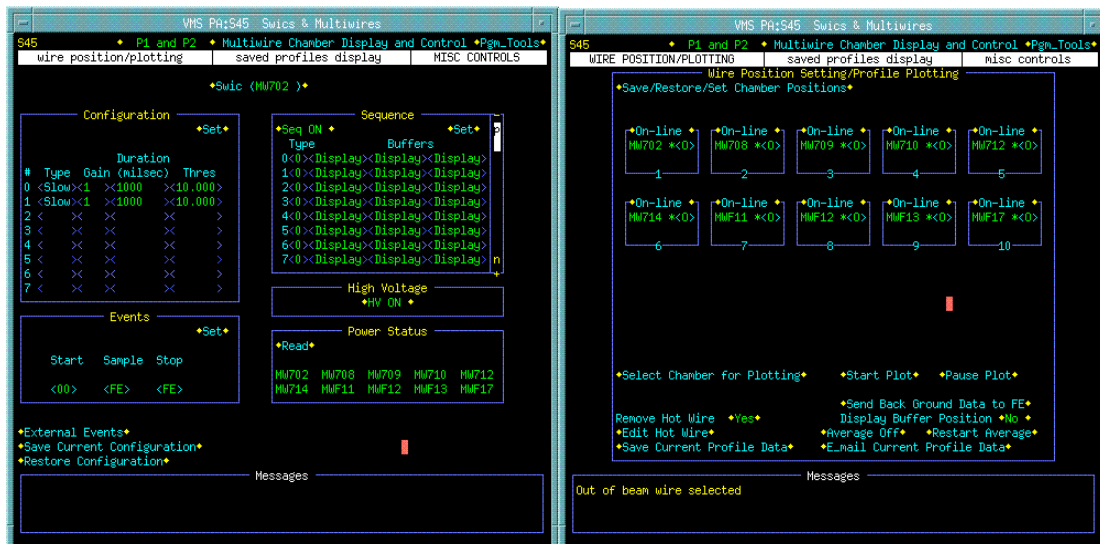
## Chapter 4: Diagnostics

The diagnostics available for checking on the beam trajectory through the SY120 beam line vary in the different sections of the Switchyard (basically for historical reasons only). Thus each section is addressed independently below.

### *P1 and P2 Beam Line Diagnostics*

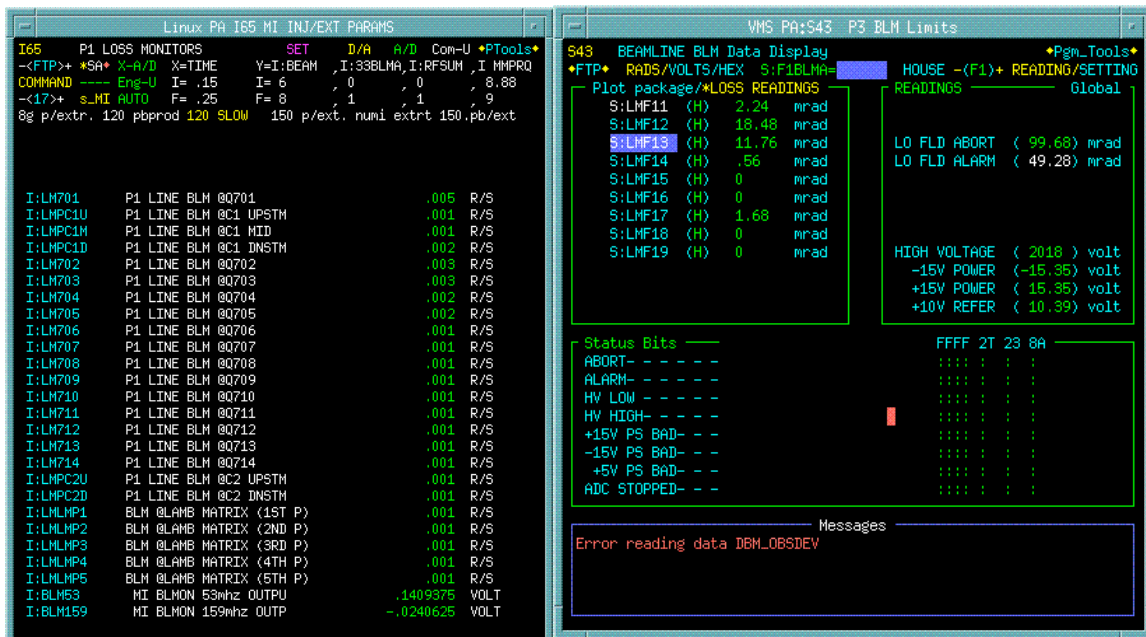
The P1 and P2 beam lines are instrumented with **multiwire chambers, beam position monitors, beam loss monitors and toroids**. In addition to transporting beam to SY120, the P1 and P2 beam lines are also involved in the transport of the high-intensity 120 GeV proton beam to the AP1 line for antiproton production and the transport of 8 GeV and 120 GeV beams during antiproton manipulations and Tevatron shots.

To preserve the emittance of the high-intensity beam to the AP1 line, the **multiwire chambers** are typically parked out of the beam. They can be used, one-at-a-time, for short periods, if permission is granted by the crew chief, Pbar experts or run coordinator. The setup parameters to check on the beam positions in P1 and are:



The SY120 beam is almost always run in slow spill mode. In this mode, the **beam position monitors and toroids** do not work. Experts are needed to run fast-kicked beam on a \$21 event if the BPMs and toroids need to be interrogated.

The **beam loss monitors** are sensitive to both the slow and fast spill SY120 beam. The ACNET pages displaying the beam losses on a \$21 event in the P1 and P2 beam lines are (note; to plot an integrated loss in P2, choose one of the 9 loss monitors and then plot I:F1BLMA (not S:F1BLMA)):



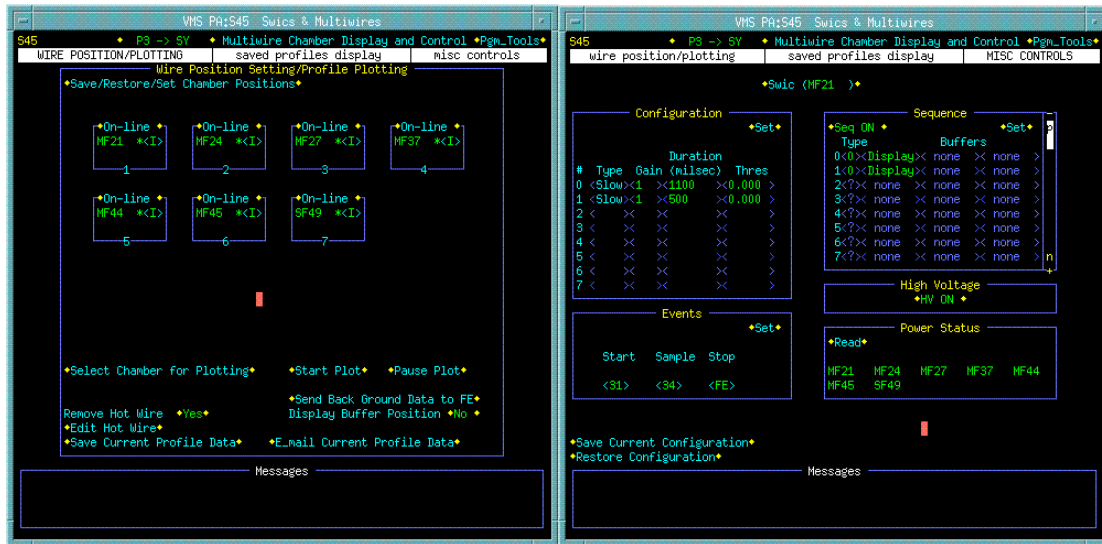
### P3 Beam Line Diagnostics

The P3 beam line is instrumented with **multiwire chambers, a SWIC and beam loss monitors**. There are no active beam position monitors in the P3 beam line.

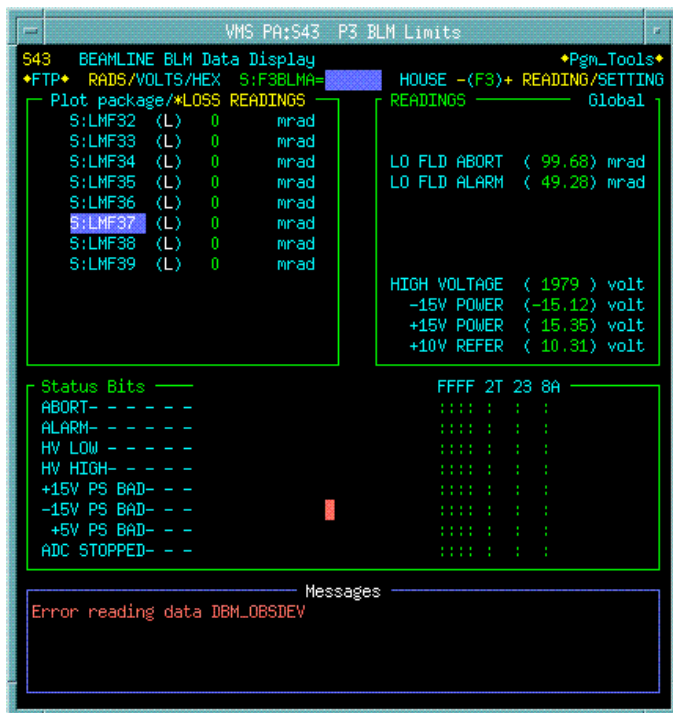
S49 is a **SWIC** and the other 6 Chambers in the P3 line are **multiwire chambers**. They are typically left out of the beamline to help preserve the SY120 beam emittance.

**Note: inserting these chambers into the beam should be done with care between \$21 events; if the SY120 beam hit one of these chambers as it was being inserted it could cause the Tevatron to quench.** The beam position in P3 can be seen by configuring the chambers as shown:

# Switchyard Rookie Book



The P3 **beam loss monitors** are connected to the old Main Ring loss monitor electronics. They can be integrated by ACNET as shown (again, the integrator can be assigned to one of the loss monitors and plotted as M:F3BLMA (not S:F3BLMA):





### Continental Switchyard Beam Line Diagnostics

The SY120 beam line through the continental switchyard, Transfer Hall -> Enclosure B -> Enclosure C -> F1,2,3 manholes, is instrumented with **SWICs, beam loss monitors, and Secondary Emission Monitors (SEMs)**. Beam position monitors do exist in these enclosures but they are not connected to any readout hardware at this time.

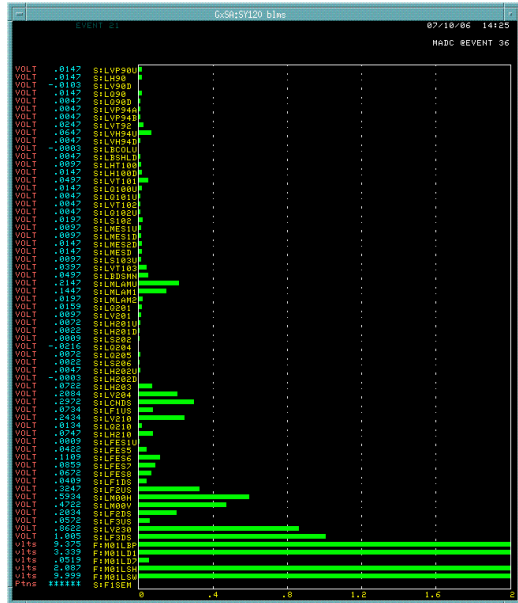
The **SWICs** in Continental Switchyard are sometimes left in the beam (this can help create small multiple-scattering tails on the beam that allow for more stable splitting of the SY120 beam, especially if the intensities requested by MTest and MCenter differ by a large factor.)

Typical ACNET settings and displays of the SWICs are:



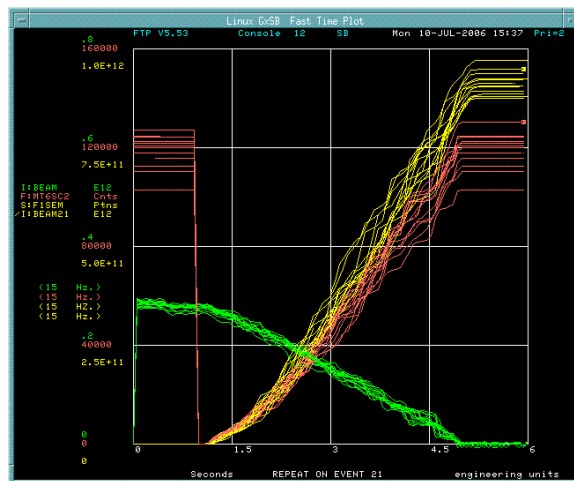
# Switchyard Rookie Book

The Continental Switchyard losses can be plotted using the new BLM display program, S43, as shown:



## Secondary Emission Monitors

Secondary Emission Monitors (SEMs) measure the integrated beam intensity per pulse. The SEM in the F1 enclosure, S:F1SEM, is useful for checking the transmission of the first 2 kilometers of the SY120 beamline as shown:



If the apparent transmission as measured by S:F1SEM/I:BEAM21 is less than 75%, there is some anomalous beam loss occurring somewhere upstream (see the [Tuning Guide](#)).

### ***Meson Area Beam Diagnostics***

The SY120 beam is typically split vertically into three (currently 2!) beams by the septa in the F1 enclosure. The upper beam is called the MWest/MTest beam line in M01 and beyond. The middle beam is called the MCenter beam in M01 and beyond. The lower beam (historically the MEast beam) would be absorbed on the Meson Target Train in M01 (but it currently is disabled!). The beam lines are monitored by **SWICs, SEMs, Ion Chambers, and scintillation counters** (in low-intensity secondary beam regions). MTest and MCenter both have high-intensity primary beam and low-intensity secondary beam regions of the beamline. This large range of intensities that need to be monitored determines the diagnostics used to monitor the beam.

The **SEMs**, F:MW1SEM and F:MC1SEM, monitor the primary 120 GeV proton intensity in the two Meson beamlines at the entrance to the Meson Target Train (downstream end of M01). Note that if the MWest beamline is not energized, the upper proton beam impinges off-center on F:MC1SEM, and thus, its reading is unreliable in this instance. Similarly, the lower or MEast beam always impinges on the lower edge of F:MC1SEM and again invalidates its reading if there were any intensity in the lower split beam (this shouldn't happen with FSEP8 disabled!).

When the MCenter beam is run in pion mode, the ion chamber, F:MC6IC, is used to monitor the primary proton intensity hitting the secondary beam production target in MC6.

In the secondary beam regions of MTest and MCenter, the beam intensity is low enough that individual particles, protons, pions, kaons and electrons, can be counted directly with scintillation counters. These counters need to be adjusted by experts to ensure that they are efficiently counting individual charged particles.

If the rate of particles registered by a scintillation counter exceeds 1 million counts per pulse, the counter is probably becoming inefficient, and, more importantly, the radiation safety envelope of the experimental enclosure, MT6 or MC6/7, will be exceeded – turn down the number of booster batches and then call an expert!

# Switchyard Rookie Book

Notes:

## Chapter 5: Controls

This chapter will deal with controls of the Switchyard and External Beamlines. This includes looking at the TLG modules used for 120 GeV operation, the CAMAC link and associated cards used, and the QXR VME.

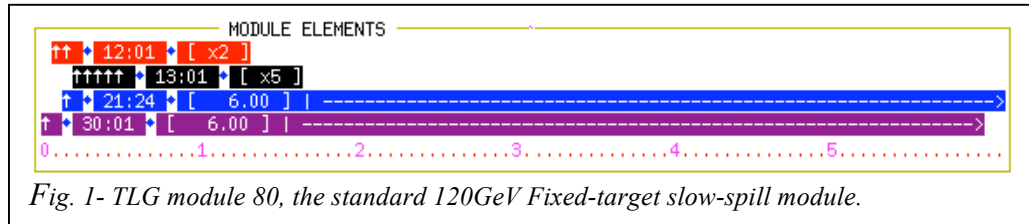


Fig. 1- TLG module 80, the standard 120GeV Fixed-target slow-spill module.

Nominally, beam is sent to SY120 in a slow spill employing QXR to deliver a steady flow of beam throughout the cycle. To do this a timeline with a slow-spill module, such as module 80, must be loaded into the timeline. Module 80, shown in *fig 1*, is roughly 6.2 seconds long with a 4.2 second flattop, the latter of which determines the length of the spill.

The first thing that should be noted about this module is that it is a multibatch module. One can see that from the number of Booster batches are being called for on the Booster reset for Fixed Target, \$13. The module starts out by playing out a \$30 indicating that SY120 will be taking beam. This is followed by two pre-pulses in Booster on the \$12s and a Fixed Target reset in Main Injector on the \$21. Once these have happened, all the machines are ready and beam is injected into Main Injector, ramped to 120 GeV, and spilled to Switchyard over about 4 seconds.

Fast Spill (or single-turn extraction from the Main Injector) to the Switchyard is a special case, seldom used, that should only be used when experts are present.

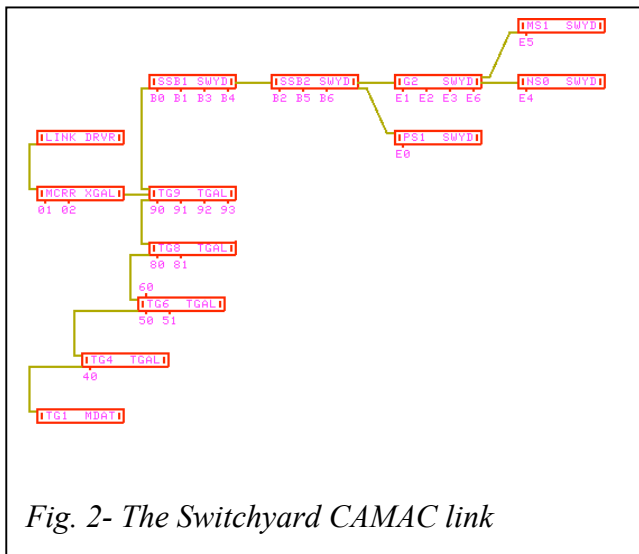
### CAMAC Link

Like other areas of the Fermilab complex, there is a CAMAC link stretching into Switchyard and, like other areas of the Fermilab complex, not all of what is on the Switchyard link actually pertains to Switchyard. Several CAMAC crates in Transfer Gallery, in the MCR, and in the MAC room are also on the Switchyard CAMAC link. For information on this and the other CAMAC links around the complex see the [Links section](#) of the [controls rookie book](#).

# Switchyard Rookie Book

## CAMAC Cards

The following is a list of the CAMAC cards used in Switchyard and the External Beamlines. Further information on each of these modules can be found at [http://www-bd.fnal.gov/controls/camac\\_modules/cXXX.htm](http://www-bd.fnal.gov/controls/camac_modules/cXXX.htm) where XXX denotes the 3-digit module number. Many of these are touched on in the [Controls Rookie Book](#) in the [Controlsopedia](#).



**057** - A stepping-motor controller module.

**080** - A parallel I/O interface module that acts as the interface module between a microprocessor and its associated CAMAC crate (such as in our BPM system). Some microprocessors use one parallel bus (Multibus) whereas the CAMAC Dataway is a different parallel bus.

**117 / 217** - A Power Supply Controller. It requires a C119 as an interface.

**118 / 218** - A Power Supply Controller. It requires a C119 as an interface.

**119** - An interface between low-level electronic controls and electro-mechanical power supply control devices.

**165** - A power supply controller for many devices. The ramps are loaded from the MCR. The ramp is of the form:

$$V_{out} = SF \times (V_t \times E)$$

The scale factor,  $SF$ , is set by the D/A value entered by an Operator on a parameter page. The table value,  $V_t$ , is a time-dependent multiplier set from a C165 control page. The beam energy,  $E$ , is represented by MDAT and defaults to full scale if not specified.

**170** - A CIA crate vacuum controller.

**177** - A time delay module for many devices around the accelerator. Each module has 8 channels that may be triggered independently, and each may be referenced to as many as 15 TCLK events. Each channel has a programmable delay ranging for 1 microsecond to 65.535 seconds. Upon receipt of a trigger each channel that is enabled outputs a TTL pulse that may be used to trigger any other device.

**178** - A TCLK repeater/decoder module. This module decodes the TCLK events and fans them out to the rest of the crate.

**181** - Provides basic digital input and output control facilities. It is a modified version of the C180 module.

**184** - Provides basic digital input and output control facilities. It is considered by the controls department equivalent to the C181 module and is recommended for new applications or as a replacement for a C181 module.

**185** - Provides basic digital monitor facilities for devices.

**190 / 290** - A module that interfaces the MADCs around the accelerator to the controls system. It can support up to 128 channels, and is capable of supporting up to 6 plots at a 2.1 kHz rate or a single channel at 70 kHz. It is able to determine which of the devices under its care are in an alarm state, and can decode events on the accelerator clock system.

## Switchyard Rookie Book

**200** - The Abort Concentrator Module. This card accepts up to 8 inputs from devices in a given service building. If the permit signal originating from a device disappears, an abort is generated, dropping the beam permit.

**333** - A customizable module able to track up to eight 24-bit binary channels. Each channel can count inputs having a frequency in excess of 25MHz. Channels are cleared with TCLK events.

**453** - A waveform generator/power supply controller. The ramps are loaded from the MCR. The ramp is of the form:

$$V_{out} = SF_1 \times (m_1 \times f(t)) + SF_2 \times (m_2 \times g(M_2)) + SF_3 \times (m_3 \times h(M_3))$$

Where  $SF_x$  are the scale factors,  $m_x$  is either 1 or a raw MDAT reading divided by 256,  $f(t)$  is a time-based ramp, and  $M_x$  is an MDAT channel. The  $g$  and  $h$  ramps then correspond to their respective MDAT channel. The  $f$ ,  $g$ , and  $h$  tables as well as  $SF_x$ ,  $m_x$ ,  $M_x$ , and trigger events can be set from a C4XX ramp control page such as S12.

**489** - A common GPIB interface module with more memory than a C488

### **S:VT210**

S:VT210 is a special case from a controls standpoint. The supply has an embedded microprocessor (VT210.fnal.gov), which takes the place of the C453 card. ACNET commands are passed to the supply by means of BADMAB (badmab.fnal.gov), the ACNET/MOOC bridge system. BADMAB is a black VME chassis mounted in the Transfer Gallery Micropit (TGS-120). In the case of a communications failure one should start by rebooting BADMAB. If that fails to bring back communications, power down the bulk supply and then reboot the Master Regulator chassis for VT210. This will reboot the internal supply microprocessor.



**QXR VME**

The QXR VME front end, located at MI60, is responsible for ramping a set of quadrupoles in the Main Injector such that the beam tune shift slowly moves toward the  $\frac{1}{2}$  resonance, thus causing the beam to increase in size in the extraction region and hence jump the electrostatic septa at MI52. The QXR VME then monitors the circulating beam (I:BEAM) and compensates the rate the tune changes in order to maintain a constant beam flux during the extraction period to switchyard.

To a large degree, QXR can be fine-tuned using the parameters on subpages 3 and 4 of I65 under *120 SLOW*. Some of the more useful parameters along with their use are listed below. The major parameters that regulate QXR extraction are gain (fast feedback loop and memory), and the elements related to memory smoothing: memory learning rate, and memory retention rate.

I:QRESET – The QXR memory reset parameter. To reset the memory set this parameter to 1. Following the next \$21, I:QRESET will return to 0 indicating that the QXR ramp has been wiped and it will start learning in again from a DC level dictated by I:QXTSL.

I:QXTSL – The QXR flattop start level. QXR will come up to this value and play out any ramp that it has learned in. If its memory has just been cleared, QXR will play out this level for the duration of the cycle and start learning in based on feedback. If the flattop start level is too far off, it will be marked by very rapid change at the beginning of the cycle. It has recently been set to around 10 Amps.

I:RBTAB5 – The QXR VME reboot parameter. **This should only be used after consulting a QXR expert!** Once it has been established that a reboot is necessary, issue a reset to this parameter and then turn on I:NQST1 to complete the reboot. Note that rebooting the VME from D31 will only issue the reset to I:RBTAB5 and QXR will not come back until I:NQST1 has been turned on. Furthermore, QXR will not act on the beam until I:QXTEN is set to 1.

I:QXTEN – QXR's enable bit. If I:QXTEN is set to 0, QXR is not enabled and will not work to extract beam from the Main Injector. If it is set to 1, it will extract beam according to its learned-in curve.

## **Switchyard Rookie Book**

I:QGMEM – The memory gain on QXR. This will determine how fast QXR learns in.

While it can be useful to run the memory gain fairly high early on, it can accentuate bad features once the QXR ramp has been learned in.

## Chapter 6: Utilities

### ***Vacuum***

Vacuum requirements in the Switchyard and Fixed Target beamlines are considerably less stringent than in other parts of the accelerator, because protons only pass through once. The ideal pressure is around 1 to 10 microns (one micron =  $10^{-3}$  torr), except for the septa, which need to achieve about  $10^{-7}$  Torr to prevent sparking.

To isolate the Switchyard into different regions to accommodate the different requirements, "windows" made of ~3-mil thick titanium are installed at strategic points. The thickness is sufficient to withstand 1 atm pressure differential, but is practically transparent to 120 GeV beam. Windows are placed at either end of each set of septa. The windows are recognizable in the tunnel by the 5-1/2" quick-disconnect flange.

The beam line vacuum is maintained by a roughing pump/Roots blower combination. The Roots blower improves the vacuum by a factor of about ten. These pumping stations are continuously running. Both pumps operate simultaneously to maintain a vacuum of  $10^{-3}$  torr. The relatively poor vacuum can be attributed to the limitations of pump capabilities and outgassing from the 14" carbon steel "sewer pipes" between enclosures.

Vacuum is maintained separately in the septa with ion pumps. Of course, a roughing pump and turbo are required for the initial pump-down, after which a valve isolates them. Pressure in the septa should be maintained around  $10^{-7}$  torr.

Some of the decommissioned Neutrino, Muon and Proton beam lines in the Switchyard are also maintained under vacuum by the mechanical support group for preservation purposes. Be aware that some active devices are in the G1 stub of Encl C, D & E and G2 and show up on the G2 vacuum subpage.

# Switchyard Rookie Book

## ***Vacuum Components***

### *Pirani gauges*

Pirani gauges measure the vacuum in the beam pipe from atmosphere (760 torr) down to  $1 \times 10^{-3}$  (1 micron). They are used throughout Switchyard and Meson.

The M01 Lambertson MW1W is interlocked to a Pirani gauge. If the gauge is not in an acceptable range the Lambertson magnet will not turn on.

M01 Lambertson      M01PG1  $\leq$  1.25 volts or .1 torr.

### *Cold Cathode Gauges*

Cold cathode gauges measure vacuum levels below  $10^{-3}$  Torr (1 micron). Currently, the only cold cathode gauge in use in Switchyard is FSCCI, which measures the vacuum at the only location required to achieve vacuum higher than 1 micron, the FSEP7 and FSEP8 electrostatic septa.

### *Mechanical pumps*

Mechanical pumps operate down to about 10 microns ( $10^{-2}$  Torr) and are used in the majority of the beamlines. Mechanical pumps have an oil-sealed chamber in which a series of round discs spin on a shaft. As the discs press against the walls of the chamber, air molecules are pushed toward an opening and vented into the atmosphere. A smoky vapor emanating from a mechanical pump usually implies that it is pumping large amounts of air, in which case the mechanical group should be notified.

### *Ion Pumps*

Ion pumps are used on the FSEP septum magnets. They produce a vacuum by ionizing the molecules of air in the chamber, and driving them into a special material, which removes them from the chamber. Their range of operation is  $10^{-7}$  to  $10^{-8}$  Torr.

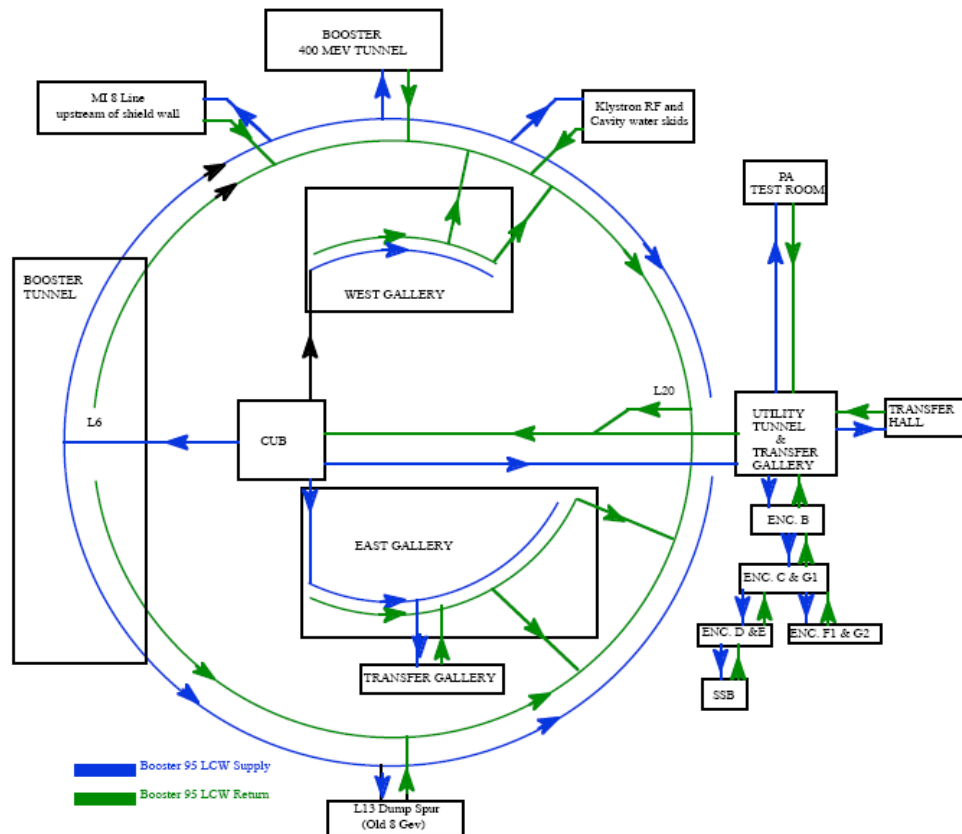
### *CIA Crates*

The CIA crate is the electronic readout and controls hardware designed for the vacuum system. It has dedicated cards and slots for the different device types. One crate can handle up to 24 Pirani gauges, 24 cold cathode gauges, 12 valves and 4 pump setups.

**LCW****Switchyard**

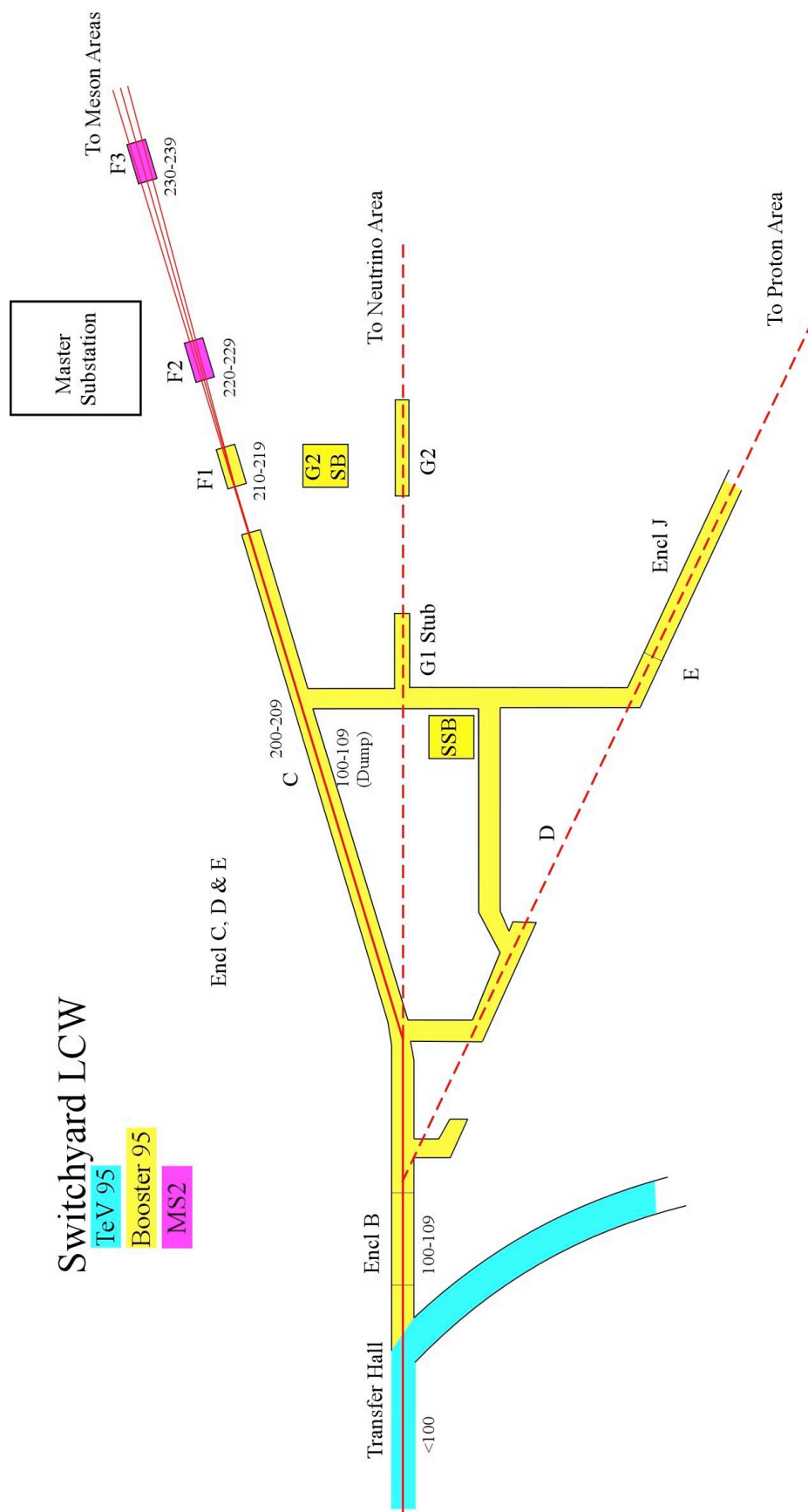
The LCW system for Switchyard is a branch of the Booster 95 degree system. From their origin at CUB, the supply and return lines enter the Utility Tunnel. Several taps in the tunnel provide cooling for Switchyard power supplies in the Transfer Gallery upstairs before the lines take a plunge into Enclosure B. For the most part, the lines run parallel to the magnets near the floor, often for long stretches of Switchyard that require no water cooling. (Trims, for example, are air-cooled.) When a string of EPB magnets appears, a small, separate set of headers is set up to supply it.

The main lines run all the way down Enclosures B and C; they also supply EPB magnets in F1 and G2, as well as G2 service building power supplies. There is a major branch near the beginning of V100 that supplies enclosures D and E; eventually SSB power supplies tap off this line. The supply pressure is kept at about 120 psi, and the return at about 40 psi.



The P2 and P3 line magnets and power supplies are cooled by the TeV 95 LCW.

## v2.2



## MESON LCW

Meson magnet and power supply cooling is provided by 2 LCW systems (MS2 & MS6) and one RAW system (M01). Start-up instructions are located at the skid.

## MS2 LCW

MS-2 LCW system services enclosures F2, F3, M01, M02, M03, M04, M05 and upstream devices in MC6 (up to MC6Q3), as well as power supplies in service buildings MS1, MS2, MS3 & MS4. It also cools the heat exchanger on the M01 RAW water system that cools the Meson Target Train beam absorbers.

### *System Operation*

This system normally requires **one pump** for proper operation. The normal system operating pressure is approximately 180 psi.

**PLEASE NOTE:** During the winter some of the MS-2 air towers are blanked off and tagged. **Do Not fill these towers or turn on the fans.** All of the fans in this system have the ‘Hand’ position switch disconnected.

## MS4 LCW

The MS4 LCW system is not currently used and has been partially dismantled.

## MS6 LCW

MS-6 LCW system services MC6 downstream devices (after MC6Q4), MC7, MC8, MB7, MT6-1, MT6-2, MP7-9, MP Lab, MW7-9, MW Lab, ME7-8, and ME worm, as well as power supplies in service buildings MS5, MS6 & MS7.

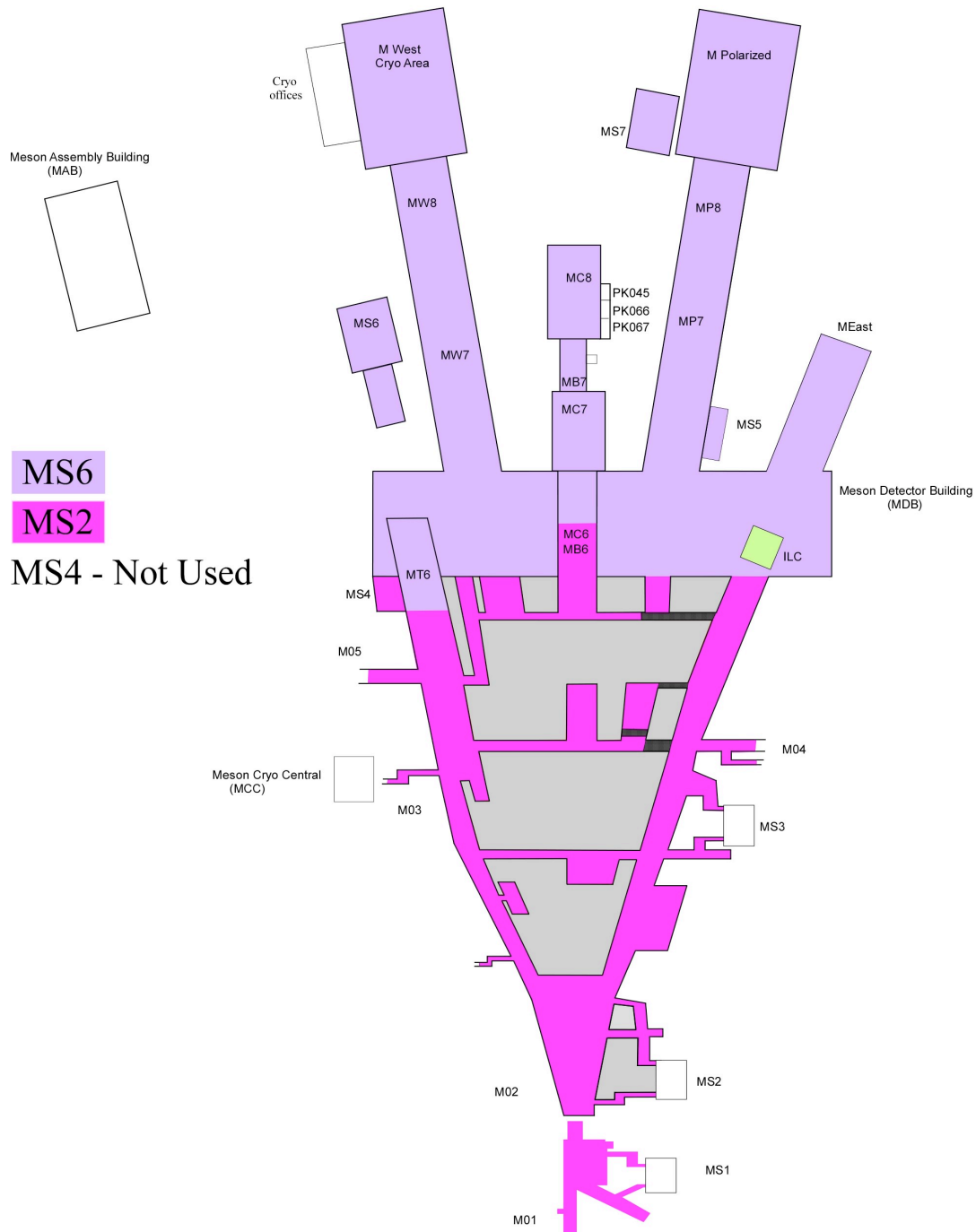
### *System Operation*

This system normally requires two pumps for proper operation. The normal system operating pressure is approximately 230 psi.

# Switchyard Rookie Book



## Fermilab Meson Area LCW



spb 28 Oct 09



## MESON RAW

A smaller cooling system is the **RAW (RadioActive Water)** system. It's a closed loop system, totally isolated from all other cooling systems. This is necessary because its primary function is to cool target piles and beam dumps, which cause the water to become highly radioactive or tritiated. **The RSO must be notified before any work done on a RAW system, or in case of a leak.**

### *M01 RAW System Operation*

This is the only RAW system currently in use in Switchyard or Meson. It is used to cool beam absorber pile between M01 and M02 (usually called the Meson Target Train). The system has the rated heat load capacity of 150 kW. It also features computer readouts and variable flow rates of 5 to 60 gpm with a constant pressure of approximately 115 psi.

### ***System Features***

Incorporated in this system are the following:

1. The M01 RAW system requires only LCW cooling to satisfy the Radiation Safety Group. On RAW systems with a maximum load of 150 kW or RAW installations in which the cooling water must be supplied at a temperature lower than can be provided by the LCW, we have installed a water-to-water heat exchanger that uses ICW to pre-cool the LCW to a lower temperature. This eliminates the need for costly and complicated chillers that have been used in the past. **On the M01 RAW system the water-to-water heat exchanger portion of the system is not used.**
2. The surge tank in this RAW system is open to atmosphere. This helps release any hydrogen build-up that may occur and eliminates the need for recombiners and extra alarms.
3. The main control box for this system is located in the MS-1 service building. The front face of the control box is diagramed to give the operator a visual readout of the RAW system it is operating. A flow diagram of the RAW system contains indicators for flow rates and temperatures. Lights are provided on the front of the control box to give the operator an 'instant' look at the RAW system status.

# Switchyard Rookie Book

## Composition of a Water System

### *LCW (Low Conductivity Water):*

LCW starts as industrial water from one of Fermilab's ponds that is processed through a deionizer loop, which takes minerals out of the water.

### *ICW (Industrial Cooling Water):*

ICW is industrial water from one of Fermi's ponds. We use Casey's pond.

### *Pre-Strainer*

A pre-strainer removes rocks, dirt, and other debris from the industrial water before it goes to the LCW system.

### *String Filters*

This is a more refined means of filtering the industrial water. It filters-out debris not caught in the pre-strainer.

### *Deionizing Loop*

The deionizing loop consists of 4–6 deionizer bottles, which contain a mixture of anion and cation. The bottles act as filters, removing minerals found in the industrial water, thereby lowering the electrical conductivity of the LCW system. This filtering process is known as “polishing” and prevents electrolysis across the ceramic voltage potentials of the magnet and deterioration of the hose barbs in power supplies and the system piping. A RAW system has only one deionizer bottle.

### *Resistivity Meter*

The Resistivity Meter measures the electrical conductivity of the LCW water. It helps to determine if the LCW system needs more “polishing” as well as indicating when the deionization bottles need replacing.

### *3-way Makeup Valve*

This valve allows the circulation of LCW water through the deionizing loop or ‘make-up’ water (ICW) to fill the system.

### *Expansion Tank*

The expansion tank allows for expansion and contraction of the water due to the temperature changes during operation and for monitoring the system's water level. Float switches in the tank indicate the water level. Alarms are shown by LEDs on the front control panel. The float switches are called:

1. Low Level
2. High Level
3. Make-Up On
4. Make-Up Off

### *LCW Pumps*

There are usually 2–3 pumps per system driven by 40, 50, 100, or 150 horsepower AC induction motors. The RAW systems have two pumps but only one is used. The second pump is valved off and used as a backup.

### *Variable Speed Controller*

Variable Speed Controllers were implemented in some water systems to adapt to changing magnet loads. Its flexibility allows the cooling system to match the heat load without changing different pump configurations. It is used alone during shutdown to keep the system “polished” and for special running of analysis magnets.

### *Water-to-Water Heat Exchanger*

It is a shell and tube construction wherein LCW water passes through the shell side of the exchanger and cooling ICW water in the tube. This is a controlled process when ICW cooling is required. The RAW systems usually have two heat exchangers, ICW-to-LCW and LCW-to-RAW.

### *Water-to-Air Cooling Towers*

This is a radiator-type construction wherein return LCW water from the magnet and power supplies pass through air towers. Electric-driven fans turn on to control the temperature.

# Switchyard Rookie Book

## *Water-to-Water Heat Exchanger with Air Cooling Towers*

Pre-cooling air towers help conserve ICW cooling water needed for the heat exchanger during the summer. The air towers are not used in the winter.

**PLEASE NOTE:** Air Cooling Towers are for emergency use only.

## *Air Compressor*

This provides required air pressure to the system. The air pressure is regulated at 70 psi.

## *Pressure Regulated Valve*

These valves regulate the pressure for other devices in the system that require lower pressure. The relief valve relieves pressure if the pressure is greater than the set point.

## *Pressure Gauges, Pressure Controller and Pressure Switch*

These devices monitor pressures, maintain regulated pressures, and indicate if pressure is ‘good’ or ‘bad’ in all systems.

1. Power supply rooms require 120 psi for operation.
2. LCW operating pressure is between 180–260psi.
3. RAW operating pressure is 115 psi, 160 psi for a “Big Brother” RAW system.

## *Controls Box*

The control box contains the electronic circuitry used to monitor the water temperatures, flow rates, and expansion tank water level of each system. Red LEDs located on the front panel of the control box indicate alarm conditions. Under certain alarm conditions, the control box circuitry will shut down the system. LCW control boxes are blue and the RAW boxes are red. Their design and function are basically the same.

## *Flow Probes*

The Flow Probes monitor the flow rate in the header pipes as well as the total flow of the system. Flow rates for a RAW system vary from 5 gpm to 60 gpm. The normal flow rate through a RAW deionizing loop is 5–10 gpm. The normal flow rate through a LCW deionizing loop is 15–20 gpm.

*Temperatures Probes and Gauges*

The Gauges monitor the Supply and Return temperatures for each water system. The Probes indicate real temperatures that are converted into an electrical signal, which is used in the systems control box.

# Switchyard Rookie Book

Notes:

## Chapter 7: Meson Beamlines

The Meson Beamlines, MTest and MCenter, currently service two experimental areas, the Meson Test Facility in enclosure MT6A/MT6B and the MIPP spectrometer in MC7. The two beamlines are designed to operate more or less independently; changes in the running conditions of one should not affect operations in the other and beam may be provided to one experiment or both experiments without special configuration changes. Both the MTest beam and the MCenter beam have a 120 GeV proton mode of operation and a lower energy, secondary hadron beam mode of operation. These two modes are usually referred to as the proton mode and the pion mode to indicate the majority species of particle type incident on the experimental detectors in the secondary beamline.

### ***Meson Center***

Meson Center, commonly referred to as MCenter, can be divided into two distinct areas. The first is the primary proton beamline, which runs from the F1-enclosure splitting septa through the MC1D critical device to the MC6 enclosure. At the upstream end of MC6, the beam can interact with a long, narrow solid copper target. The secondary beam spectrometer in MC6 can be operated in two modes.

***MCenter Pion Beam Mode:*** the secondary produced particles from the MC6 target enter the MC6 spectrometer, are momentum analyzed, and then transported to the experimental area MC7. In this mode, there is an upper current limit on the MC6D bend dipoles that prevent the MC6 spectrometer from transporting particles of energy greater than 80 GeV to the MC7 experimental hall.

***MCenter Proton Beam Mode:*** in this mode, the MC2PH pinhole collimator is required to be in the beam and the MC2Q1/2 doublet must be off. The attenuated proton beam is then transported all the way to the MC7 experimental tunnel (the copper target in MC6 is usually removed from the beam in this mode).

# Switchyard Rookie Book

## ***Meson Test***

Meson Test, or more commonly MTest, can be run in three different modes. In all cases the primary protons from the Enclosure-F1 triple split are transported through MW1W (the critical device) to an aluminum target on the upstream end of the Meson Target Train. The three modes determine whether the uninteracted protons traversing this target, the produced secondary pions produced in this target, or pions produced on the new target in M04, MT4TGT, are transported to the Meson Test Facility in MT6.

***MTest Proton Mode:*** In proton mode, most of the uninteracted 120 GeV protons that survived the Meson Target Train target are absorbed on the pinhole collimator in the M03 MTest alcove. The MT2Q1/2 and MT3Q1/2 doublets are also required to be off so that 120 GeV protons cannot be focused through the pinhole collimator. The highly attenuated 120 GeV proton beam is then transported to the Meson Test Facility in MT6. Save/Restore file 400 is supposed to contain the most recent nominal tune for the 120 GeV tune of the MTest line.

***MTest Pion Mode:*** In pion mode, the 120 GeV protons which interact in the 12” aluminum target on the Meson Target Train create copious lower energy pions (and other particles) at 0°. The MT2W1 double dipole string then separates the secondary hadrons from the more copious uninteracted 120 GeV proton beam (the protons are absorbed on the steel pile in M02). The pions are then transported to the MT6 test facility. In this mode the pinhole collimator is removed from the beam in order to maximize the flux of pions reaching MT6, and the dipole magnets in M02 are limited by interlocks to 66 GeV equivalent current or below.

***MTest Low Energy Pion Mode:*** In this mode, 120 GeV primary protons (the target in M01 is removed from the beam) are transported to a target, MT4TGT, in M04. The magnets downstream of MT4TGT are limited by interlocks to 30 GeV equivalent excitation, and must use the low energy magnet supply, i.e. MT5EL, not MT5E, etc. Save/Restore files 401 through 405 are supposed to contain the most recent nominal tunes for the 1 GeV, 2 GeV, 4 GeV, 8 GeV, and 16 GeV settings for MTest respectively. On ACNET page S18<30> set the energy to run the appropriate script for changing the pion energy while in the MTest Low Energy Pion Mode.



Notes: